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FOUNDED BY C. E. LINEBARGER

A Journal for all SCIENCE AND MATHEMATICS TEACHERS

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"The true test of civilization is the kind of man the schools produce."
—*Emerson*

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SCHOOL SCIENCE AND MATHEMATICS

VOL. XXVIII No. 6 JUNE, 1928 WHOLE No. 242

THE TREATMENT OF EXTREME AND MEAN RATIO IN GEOMETRY CLASSES.

BY JOSEPH A. NYBERG,
Hyde Park High School, Chicago.

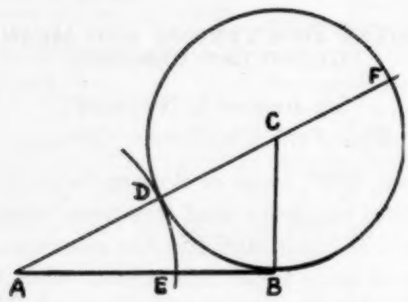
In the October, 1927, issue of SCHOOL SCIENCE AND MATHEMATICS, the editor suggests that teachers should write more about how they "do their stuff" in the classroom; that is, how their treatment of some topic differs from what is found in the textbook. Or, what special devices are used in presenting certain topics? In mathematics the devices consist in most cases of some unusual metaphors or comparisons, some problem to introduce a subject, or it may be merely that the language of the text is replaced by some phrases from the daily life of the pupil. This article will therefore discuss how I have found entertainment in handling extreme and mean ratio. This topic has been eliminated from the new (1924) requirements of the College Entrance Examination Board. I have found, however, that their requirements in geometry (unlike their requirements in algebra) are now so modest that I always have time in which to discuss this topic.

Instead of presenting the topic here in the same order in which I do it in class, I shall begin at the point where the class has learned (in ways that will be shown later) how to divide a line in extreme and mean ratio and is about to prove that the construction is correct. The figure has been constructed on the blackboard and the class has decided that the hypothesis (that is, those facts about the figure which are used in making the figure) is:

$$BC \perp AB, \quad BC = \tfrac{1}{2}AB, \quad CD = CB, \quad AE = AD.$$

The reader will notice that the figure has not been lettered in a haphazard manner. We began with the line AB. The next point that was found was called C; the next point was called D. The letters of the alphabet are always used in alphabetical order. If a pupil forgets how the figure was constructed, the letters in the figure actually suggest the construction because the point C must be located before the point D, and the point D precedes the point E, etc.

We wish to prove $\dfrac{AB}{AE} = \dfrac{AE}{EB}$. (1)



As a hint I say that AC must be prolonged to intersect the circle again, and then I adopt my usual attitude toward the class, an attitude that I use whenever we are trying to prove any statement; namely, posing like Rodin's statue of The Thinker, I review the previous theorems that we can use. By "can use" I mean that there exists some theorem whose hypothesis is fulfilled by the hypothesis of our problem. Evidently it is not a theorem about parallelograms because there are no parallelograms in our figure; neither is it a theorem about chords in a circle for there are no chords in our circle; neither is it a theorem about the bisector of an angle for there is no such bisector in the figure. What have we in the figure? A Radius! And a line perpendicular to it at its end! Ah! A Tangent! I must find a theorem about a tangent. I may add that I talk to the class in much the same words as I have written. I appear to have been soliloquizing, and finally I break forth with "AH! A tangent" and the class is alert.

Some of the pupils will be ready to suggest the correct theorem at once. The others are told to turn the pages of the book until

they find a theorem about a tangent. "Look in your tool chest," I say, "and find the correct tool for your purpose. Each theorem is a tool that will do certain work; one theorem will prove that a point lies on a certain line; another theorem will prove certain triangles are similar. Select the correct tool; don't try to saw wood with a hammer." After a while we state the theorem and write on the board:

$$\frac{AF}{AB} = \frac{AB}{AD}. \qquad (2)$$

The problem has now become simply: How can we change proportion (2) to proportion (1)? Will inverting the fractions change one proportion into the other? Will it do any good to interchange the means? The second proportion contains the letter F, and the first one does not. How can we get rid of the letter F? What can we substitute for AF? Substitution is an exchange of one thing for another of equal value, just as after Christmas you exchange the presents you do not want for something you do want, or, as in the lunchroom, you exchange a nickel you do not want for a sandwich that you want very much. We agree to accept AD+DF for AF, and write

$$\frac{AD+DF}{AB} = \frac{AB}{AD}.$$

But we still have the letter F which we do not want; and we have also the letter D which we do not want. After some suggestions we accept AE for AD, and accept AB for DF. Hence

$$\frac{AE+AB}{AB} = \frac{AB}{AE}.$$

We have now done all the substituting we can. What else have we learned that we can do to a proportion? The class once learned that there are five permissible and useful operations that can be performed on a proportion, just as there are certain useful operations that can be performed on a person. We try them. Interchange the means? No good! Interchange the extremes? No good! Invert the fractions? No good! Add the

denominators to the numerators? No good! Subtract the denominators from the numerators? Ah! Eureka! And finally we invert the fractions.

The above presentation may sound clownish but it succeeds in emphasizing that to solve any problem in geometry we must first find a previous theorem that "fits" the problem, and then use the customary operations of adding, substituting, etc., until we obtain what we want. A collection of theorems is like a collection of tools each of which can do certain work. Whenever a new theorem is proved it is well to mark it with a label stating what it can be used for. The textbook is nothing but a tool-chest. Further, it does no harm to mention some of the theorems that can not be used. It is just one way of having a review of previous work.

Although the topic of extreme and mean ratio is omitted from the requirements of the College Entrance Examination Board and also recommended for omission by the National Committee, it is a very useful topic for correlating algebra and geometry, and I usually present the work in the following order.

After reading the definition in the text we draw a line on the blackboard, mark it 16 inches, and then try to guess where the point of division would be. If the longer segment is 12 inches, then 16/12 should equal 12/4 which it does not. If the longer segment is 10 inches, then 16/10 should equal 10/6 which is fairly close, and we see that the longer segment is about three fifths of the given line. This arithmetic work is very useful in making the definition clear. Then, as usual, when arithmetic fails we call on our good friend Mr. Algebra. We let x equal the length of the segment, and find we must solve the equation $16/x = x/(16-x)$ or $x^2+16x-256 = 0$. The pupils will naturally try to solve by factoring; a few will use the formula. But when the coefficient of x^2 is 1, and the coefficient of x is an *even* number, completing the square is the quickest method; in fact, this is about the only case in which completing the square should ever be used. If the class knows nothing about the method I do not hesitate to take an entire day in which to teach the method. The class then finds that

$$x = -8\pm\sqrt{320} \qquad \text{or } x = -8\pm 8\sqrt{5}.$$

This answer is left on the board and then we find x when the line is 14 inches, next, when it is 12 inches, and so forth, until some one says that he can predict the answer for any given length, a,

of the line. If the values of x have been written in a column (the quickness with which a class grasps an idea depends a great deal on where and how the facts are written on the board) we see that

$$x = -\tfrac{1}{2}a \pm \tfrac{1}{2}a\sqrt{5}. \qquad (3)$$

All this work serves as a splendid review both of quadratic equations and of the simplification of radicals. Every class is entitled to such a review.

I now suggest that we solve $x^2+ax+a^2 = 0$ and that instead of performing all the operations, as we did for the previous numbers, we merely indicate the work. Thus we find that

$$x = -\frac{a}{2} \pm \sqrt{a^2+\left(\frac{a}{2}\right)^2} \qquad (4)$$

If a pupil cannot do this work, I suggest that in his solution for $a = 12$, he merely use his eraser, writing a every place where the number 12 appears and $\tfrac{1}{2}a$ wherever the number 6 appears. Of course 144 and 36 can actually be added; while a^2 and $(\tfrac{1}{2}a)^2$ can also be added, after a fashion, still it is more useful here merely to *indicate* the work. In fact, I suspect that many a mathematical discovery was made by some mathematician who was lazier than the others and merely indicated the work that the more ambitious ones actually performed. In mathematics it is sometimes a good policy not to do what you think ought to be done; merely indicate the work as a sign that you know what ought to be done or as a sign of your future intentions. At times I feel tempted to tell the pupils "Don't do to-day what you can put off till to-morrow; perhaps you won't need to do it." Of course only by bitter experience can we develop that good judgment which is needed in deciding what not to do.

From the value of x given in equation (4) we can then see how the method for dividing the line was discovered. For further work in algebra we reduce (4) to (3), and also show that $x = .618a$, approximately. Finally we give the geometric proof as presented at the beginning of this article.

The division of a line into extreme and mean ratio should not be studied merely to construct an angle of 36° and thereby construct a decagon. The topic as a whole is valuable because it is one of the few topics in which arithmetic, algebra, and geometry can be well correlated. Four, and sometimes five, days are needed. The algebraic work with the quadratic equations takes one day, and sometimes a second day. The next day is

used for the construction and proof as outlined in the beginning of this article. One day is used for the construction of an angle of 36° and its proof. One more day is needed to review the topic as a whole.

CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS

The Monthly Message

Committee Appointments. Warren C. Hawthorne of Crane Jr. College, Chicago, will serve as chairman of the Necrology Committee. Those who know of members who passed away during the past year will please send the information to Mr. Hawthorne in order that he may prepare a complete list for the Year Book. The committee on Local Arrangements will consist of O. D. Frank, University of Chicago High School, Chairman; Louis E. Hildebrand, New Trier High School, Winnetka, Ill; Theodore L. Harley, Hyde Park High School, Chicago.

The Mathematics Section. There will be a very interesting number on mathematics included in the general program; the section program is well under way and very promising. Following are the officers:

EDWIN W. SCHREIBER, Chairman
Graduate Student
The University of Michigan

MARTHA HILDERBRANDT, Vice-Chairman
Proviso High School
Maywood, Ill.

MARGARET DADY, Secretary
Waukegan Twp. High School
Waukegan, Ill.

General Program. There are still a few numbers to be filled. We have been fortunate in securing some of the national leaders in secondary education to appear on the program. This is the last call for further suggestions to complete our list of speakers.

When a helpful thought occurs to you regarding any phase of the annual meeting make it your duty to write the President about it. Do it now.

W. F. ROECKER, President.
Boys' Technical High School, Milwaukee, Wisconsin.

PHYSICS FOR THE PRE-MEDIC STUDENT.*

By W. C. Hawthorne,
Crane Junior College, Chicago, Ill.

The time has passed when an argument for the position of physics in the pre-medic curriculum deserves a place on any program. That question has long since been settled. But the kind of physics to be taught may still be discussed with profit. Since my first class of pre-medic students, I have been more and more of the opinion that the subject should be presented to them in a far different way than to a class of engineers. This notion was strengthened when I took a review course at the university in a class composed largely of premedics, and noted their reactions to the subject and to the method of presentation. The subject did not interest them for they saw no possible means of connecting it with their future work. The method of presentation antagonized them, for it was so different from the method of approach used in the sciences they had already studied that they could not easily orient themselves.

But when I broached to my fellow teachers the idea that premedics should be taught in a class by themselves and given a modified course, it was immediately assumed that "modified" meant "weakened" and the idea vigorously opposed. I am glad to think that opposition is much less pronounced now.

That medical students dislike the dose we are supposed to hand them is quite understandable if we consider the vehicle in which the drug is administered. The traditional course in physics grew up in connection with the study of engineering problems, and in the continual effort to make it interesting, illustrations, problems and applications were drawn from engineering work. What wonder that men looking forward to a study of the most intricate piece of mechanism known should fail to get enthusiastic over equations and diagrams and laws whose only application, as far as they were shown, was to inanimate assemblages of leather, wood and metal? Long after the principle of transfer of training had been discredited by psychologists, we continued to base our training upon it, and to assume that the man who had learned to use levers in the laboratory could, years afterward, calculate the strain on the gastrocnemius muscle. I could cite absurd solutions of this very problem in standard college physiologies to show the error of this assumption.

*Read at the Chemistry and Physics Section meeting of the Illinois State Academy of Science, Bloomington, May 4, 1928.

Let us admit at once that the teacher of physics should teach physics. He should not teach an emasculated subject, nor selected topics only. He should not attempt to teach physiology. But he should be familiar enough with a good modern textbook of physiology to get from it abundant illustrative material for the subject he is teaching. It goes without saying that without interest on the part of the student nothing will be taught. And the one thing that the medical student is interested in above all others is the functioning of the animal body. Why not vivify the study of physics, then, by calling his attention to the debt he will be under, as he goes on with his medical course, to the work of the physicists? To mention only a few items: the microscope, the cystoscope, the opthalmoscope, the electrocardiagraph, the X-ray, both as a diagnostic and a therapeutic agent, the use of radium, the knowledge of the mechanics of the circulation of the blood, the interpretation of the sounds detected by auscultation and percussion, etc., etc. Nor is the account all on one side. The contributions to the science of physics made by practicing physicians may well be a matter of pride to those of that profession. The work of Dr. Mayer, who first stated the law of the Conservation of Energy as of general application, and of Young, who dared to give evidence for the wave theory of light in the teeth of the authority of such a master mind as Newton's, are only two of several cases that might be mentioned.

Do not be bound, then, by traditional methods of presentation. If pre-medical students listen to your discussion of the stresses and strains in a roof truss, it is because of their politeness or because they can't get away. But show them a diagram of the compression system of trabiculae in the head of the thigh bone, and point out their arrangement to take up the stresses with a maximum of rigidity and a minimum of material, and see their eyes light up. Instead of questions about lifting barrels of sugar, get your problems from the muscles and bones. The engineer must be able to calculate the horse-power and efficiency of the engine that can lift a long ton of coal from the 900 foot level in one minute, but the same principles are used in getting the power and efficiency of a 200 pound man climbing a flight of stairs. Then let your students figure out how much glycogen must be converted to lactic acid by this effort, and you will have 100% of effort, if not of accuracy. But is the correct answer so very important, if you really get the interest aroused, and the principles impressed so that they will be remembered?

When we come to the study of heat, how rich the supply of illustrative material! Do they know that the Fahrenheit scale is a development from that on one of the primitive thermometers, which divided the difference of temperature between the (supposed) temperature of the human body and that of freezing water into ninety-six steps and that it was only later that the temperature of boiling water was found to be constant at 212 of these steps above that of a mixture of snow and ammonium chloride, supposed to be the coldest thing possible, which, in turn, was thirty-two of these steps below the freezing point of water. Are you teaching Charles' Law? How much greater is the volume of expired than of inspired air on a winter day? Calorimetric problems involving the different kinds of food materials are innumerable. Diathermy is coming to be of immense importance in therapeutics. When the students realize that heat may be applied as heat itself,—as radiant energy, to be converted into heat at greater or less depths below the surface dependent on the wave length of the "light" used,—or as high frequency electric currents which become heat at the points of greatest resistance, namely at the surfaces of the cells, they will have a knowledge of the Convertibility of Energy meaning much more than they would ever get by problems on the combustion of fuel in a power plant. Again, Atwater has proved that a man at rest must be supplied with 2700 large Calories daily, while a man at hard labor needs 4500 Calories. If we may assume that the difference is all converted into work, how many joules of work are done, and what is the efficiency of the man as a machine. McKendrick, in another series of experiments, measured the heat produced in twenty-four hours as 3724 Calories and estimated the work done by the heart, by respiration, and by muscles as 3.11×10^{11} joules. By how many per cent did his estimate differ from the second one given by Atwater? Once more. The combustion value of protein is 5.754 Calories per gram. But one third of a gram of urea, combustion value 2.5 Calories per gram is excreted for each gram of protein ingested. What then is the efficiency of protein as an energy producer, assuming, which is not quite the case, that all the nitrogen is excreted as urea?

What about the Second Law of Thermodynamics? Well, when they have learned that the maximum efficiency of the ideal heat engine is given by the ration dT/T, where T is the absolute temperature of the heated stuff, and dT is the drop in temperature, ask them to calculate the necessary temperature if, as is the

case with the muscles, 25% of the energy supplied is converted into work, and the final temperature is 37°C. Will it not be evident that the potential energy of the food is converted into work through some other intermediary than heat? The fact that CO_2 is not produced *during* contraction but afterward, and that most of the heat is produced after contraction verifies this supposition. Furthermore, the possible work that a muscle can do is proportional, not to its volume, as we should expect if its activity were due to a chemical change, but to its surface. To this I refer later.

In the case of the study of sound, is there any good reason why a model of the larynx rather than the violin should not be used to teach the principles of vibrating strings? A violin or sonometer simpler, you say? Possibly, but remember, no matter how simple an illustration may be it is valueless if uninteresting. And Helmholz's work with resonators in the analysis of the vowel sounds is certainly as valuable and instructive as the physics of the wind instruments. The *ear* is an organ deserving study, and full of possibilities for teaching the science of sound.

The study of light should be so fascinating to the medical student that the subject teaches itself. Illumination? Make it a study of the foot-candles required in different occupations in order to avoid eye-strain. Diffused reflection? Again, a matter of eye-health. Concave mirrors? Study the opthalmoscope. Refraction? Lenses? The eye, its defects and their correction will give you every reason for going into the subject as deeply as you desire. The crystalline lens offers a splendid chance for a discussion of spherical aberration, since its peculiar structure reduces this to a minimum. Show your students why. Give more attention to the microscope your students are using than to the telescope they may never see. Look at a catalogue of microscopes. Do your students understand the terms well enough to judge which of two instruments there described is better value for the price? If you want a knowledge of diffraction to stay with them after they have left your class, show them how diffraction limits the magnifying power of the microscope to not much more than it is now.

Don't forget that polarized light is useful for many other things than the examination of sugars. Show them a picture of how a contracted muscle fiber looks in polarized light and in ordinary light. The laboratory should own a good polariscope. Two of my old students came back from their examinations in medical college to tell me how a remembrance of what they had

learned about polarization had saved them on two important questions.

Absorption spectra can be taught as easily by reference to those of the blood and other body fluids as by the Fraunhofer lines. A solution of chlorophyll shows a good absorption band. Explain that the particular wavelengths absorbed are especially effective in the decomposition of CO_2 and the synthesis of starch, and you have again impressed the convertibility of energy upon their minds.

When we come to the subject of electricity, there is a multitude of applications that will be meaningful to the pre-medical student where the illustrations ordinarily used will be soon forgotten. When teaching the different means of producing a potential difference, why not mention that the cut end of a nerve or muscle is negative as compared with the uninjured portion. And if the student is told that the propagation of a nerve impulse is accompanied by a wave of negative electrons, traveling at the rate of 120 meters per second or less, probably produced, as Dr. Gerhard of the University of Chicago thinks, by an explosive oxidation as in a fuse, his interest is immediately stimulated. He is not likely afterwards, to be satisfied with the careless statement that "the nerve impulse is electrical in its nature," and lazily identify it with an electrical current.

Dr. Hugo Frick says that the film which surrounds the blood corpuscle is 4×10^{11} centimeters thick, and has an electrical capacity of 0.8 microfarads per square centimeter, varying in health and disease. It has been proved that the capacity and conductivity of a tumour varies with its malignancy. Will a medical student be willing to study electrical resistance and capacity after hearing this? If he will not, it will be perfectly advisable to flunk him for he will never get through a medical course. The illustrative material from the physiological processes and from the methods of the physiological laboratories is so abundant that books have been written on Medical Electricity.

The ordinary laboratory is provided with a variety of galvanometers, the working of which the student is supposed to understand. But how many students have ever seen a string galvanometer, or a capillary electrometer, which are so important in physiological investigations, or will be able to understand them when he meets them in his advanced work. Time spent in studying instruments useful only to the engineer to the exclusion of instruments used in his own work would not

seem to be the best use of the limited time for the subject.

Beyond all these topics mentioned, however, there remains something more to be said. There is one section of physics usually neglected, or at best very briefly treated, that is of so much importance that in order to give it attention, I believe we might seriously consider the omission of some things usually included in an engineering course. I refer to the physics of colloids, and to the subject of surface energy, including osmotic pressure, all of these being rather closely connected in physiological processes. These are difficult subjects, and new subjects, so that it is not easy to find material in such shape that, without preparation, it can safely be fed to sophomore students. But the body is a mass of colloids, and as soon as he opens his physiology he begins to read about them. The whole process of food assimilation seems to consist in changing from colloids of one kind to another, or from particles of one size to another, thus changing the surface energy. Probably chemical energy is rendered available as muscular energy with surface energy as an intermediary form. Again, the elements of the digested food get about from one organ of the body to another by osmosis, and not by any simple osmosis at that. It is sometimes an osmosis of molecules, sometimes of positive ions, sometimes of negative ions. The electrical charge on the separating membrane is often a factor of importance. It would seem as if the medical student should have a general knowledge of these topics before he is thrown into a situation where a familiarity with them is assumed. With this exception, however, I can see no reason why the premedic should not, in the main, study the same physics as his brother in the engineering course. But he should be in a class by himself, and his course should be enriched by illustrations drawn from his own field; not, as I have said, to teach him physiology, any more than the problems his brother wrestles with are to teach *him* bridge-building, or mining, or electrical engineering, but really to *teach him physics*, in such a way that he may *see its value, get a love for it*, and *remember a modicum of its principles for use in his future work.*

TWO MILLION COLORS.

Necktie and clothing manufacturers probably still have plenty of colors left with which to add to the brilliance of life. Altogether there are slightly over two million separately distinguishable colors possible. This is the conclusion reached by George B. Welch, of Cornell University. —*Science News-Letter.*

SOME ECONOMIC ASPECTS OF THE ALGAE.*

BY L. H. TIFFANY,†

Department of Botany, Ohio State University, Columbus, Ohio.

A rather well-known botanist is said to have this item in one of his lectures on the algae: "Economic value—uninteresting and unimportant." It is rather difficult to understand how a statement of this kind could be made if one were conversant with the facts. If this impression as to the economic importance of the algae is current at all among botanists, it may be of value to set forth rather briefly some of the economic aspects of this group of plants.

Before attempting to point out a few of the important economic aspects of the algae, it might be well to mention some of the more salient facts of classification and periodicity as a basis for further discussion.

CLASSIFICATION OF ALGAE.

Most of us learned, I presume, that there were four classes of algae (the diatoms, having doubtful "affinities," were included dubiously first in one class, then in another, or "treated separately"): greens, bluegreens, reds, and browns. Although these are very convenient designations, they do not take care of all the facts that have a bearing on systems of classification. It has been rather definitely shown that pigmentation may not necessarily differentiate among the various algae. It is a very important basic characteristic, but if carried too far loses its diagnostic value. A few examples will suffice. West[18] was the first, I think, to state that only about half of the bluegreen algae were really bluegreen in color—variations of brown, green, violet, and even red sometimes occurring. When we know more about the influence of various light rays on pigmentation in the algae, we may have some clue to an explanation of these various shades of color. Some of the so-called green algae that are really more yellowish-green than green, together with having other definite characteristics, now form a new class. Many of the green algae are decidedly yellowish at some stages of their development. In fact the bright green color is more likely to occur only in an active vegetative condition. Furthermore what shall we do with such forms as Euglena, Peridinium, Ceratium, Volvox, Chlamydomonas?

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*Presented to the Phi Sigma Biological Society of Miami University, Oxford, Ohio, Nov. 15, 1927.

†Papers from the Department of Botany, Ohio State University, No. 212.

It is just as well to say at the outset that the matter of classification has often been pursued too assiduously. "Pigeon-holing" is a pleasant game, and things must somehow be classified if we are ever to progress in making "order out of chaos." Classification as a means toward an end, not considered as an end in itself, is most essential in establishing a basis for a better understanding of organisms and their interrelations. Algae are not unlike other units comprising a classificatory scheme in that they may not remain "put." New biological data are forthcoming nearly every day, and one may find that perfectly familiar species have been adopted into new families or orders or classes and are masquerading under new names.

From a recent and stimulating book by Fritsch[5] one finds that our old four classes of algae have been dissected, pared, renovated, and rearranged into eleven classes. This classification is based primarily on the assumption of the flagellate ancestry of algae.

Some botanists and zoologists, who are ever alert to heed the biblical admonition, "Remove not the ancient landmarks which thy fathers have set," are ready to unsheath the sword and to do battle to the bitter end if one be so unfortunate as to refer to Euglena as a plant or to Volvox as an animal. These individuals seem never to stop to figure out who set the "ancient landmarks" anyway, nor to realize that the popular categories of plants and animals may not lend themselves to scientific delimitation after all. When the categories are considered from the standpoint of cows and oak trees, even a half-wit might use them as a working basis; but when such organisms as Volvox, Euglena, Phacus, or Mallomonas are considered, the separating "fence" may be rather faint.

Fritsch lists all the pigmented protophyta as algae and acknowledges the flagellate habits or algal habits of the various groups, depending upon whether their characteristics are predominantly "flagellate" (*i.e.*, longitudinal division, usually no sexuality, indefinite cell wall), or "algal" (*i.e.*, absence of longitudinal division, usual presence of sexuality, definite cell wall). On this basis certain classes are entirely flagellate, others entirely algal, and most show definitely in some forms their "flagellate" ancestry.

The following general classification of the algae, based somewhat on the recent work of Fritsch (*loco. cit.*), serves rather well to take care of the pigmented protophyta in light of recent

algological research.

I.	Chlorophyceae	green algae
II.	Heterokonteae	yellow-green algae
III.	Chrysophyceae	golden-yellow-brown algae
IV.	Bacillarieae	diatoms
V.	Cryptophyceae	brownish algae
VI.	Dinophyceae	peridinieae or dinoflagellates
VII.	Chloromonadeae	flagellate-like algae
VIII.	Euglenineae	euglena-like
IX.	Rhodophyceae	red algae
X.	Phaeophyceae	brown algae
XI.	Myxophyceae	blue green algae

Periodicity and Its Significance.

Several algologists have noted the definite periodicities of algae, and Transeau's[17] chart reproduced herewith (Fig. 4) serves to illustrate this seasonal development. This periodic "succession" of one group of algae by another group becomes of tremendous significance economically (and will be referred to later) when one realizes the enormous "turnover" occurring in a body of water during a growing season. The winter annuals are literally replaced by the spring annuals and these by the summer forms, if one is thinking in terms of relative abundance. An almost immeasurable crop are the "ephemerals" of Transeau.[17] Hardly has one of these algae completed its life history before another becomes dominant. Those of you who have watched the rapid appearance of "water blooms," their temporary omnipresence in the body of water, and their sudden decline cannot but be impressed with the fact that here is occurring a stupendous spectacle of growth, of syntheses, and of oxidations which perhaps is not exceeded anywhere in the plant kingdom.

Economic Aspects: Detrimental.

Although one hears now and then of cattle or horses, or more accurately a cow or a horse, dying *after* having eaten prolific growths of algae occurring in a pasture stream, it is doubtful if any of the animals have died *because* of the algae. As a matter of fact squirrels have been caught nibbling tender growths of Cladophora from the stones along the shores of Lake Erie, with the resultant casualties zero. Similar are the accounts of cows wading in streams with water to their midsides, plunging their heads below the surface, giving for the moment the appearance of "headless bovines," and coming up again with delectable

morsels of Cladophora or other bottom algae.‡ (We shall not discuss here whether or not this method of aquatic grazing among terrestrial animals is an acquired characteristic!)

Algae have long been known to be one of the important causal agents in the contamination of water supplies. It has been supposed that in the growth of the algae, peculiarly obnoxious products occurred causing the foul odors and bad tastes sometimes prevalent in small bodies of water. A study of the physiology of these plants, however, gives no data in support of any unusual products in spite of the fact that certain odors can oftentimes be associated with particular species of algae.

The slimy pectic material occupying peripheral regions of many green algae and most bluegreens is an excellent place of lodgment for bacteria. Then because of the tremendous rapidity of growth of many algae there is a mass accumulation with insufficient oxygenation, and various incomplete oxidations occur. The gaseous output from these incomplete oxidations together with the solid material resulting therefrom probably accounts for all the contamination. This is quite sufficient, of course, to make the water unfit for drinking.

Masses of filamentous algae accumulating on the surface of the water may be injurious to small fishes and other aquatic animals in moderately shallow ponds by preventing sufficient aeration below the surface. Moore [9] reports in addition to this the mechanical injury due to the imprisonment of the young fish in the tangled mass of filaments, sometimes killing the animal. It should be stated, on the other hand, that masses of algae may in these same ponds offer considerable shade to the water below, provide protection from larger animals, and also serve as places of lodgment and reproduction for numerous phytoplankton and zooplankton so necessary to young fishes.

Fortunately the algae can be eliminated rather easily by the application of very weak solutions of copper sulphate (blue vitriol), as was reported by Moore and Kellerman [10, 11] nearly a quarter of a century ago. Copper seems to be particularly poisonous to most plants. Concentrations as low as one part of $CuSO_4$ in a million parts of water are destructive to some algae; twice that concentration is fatal to many more; and the ratio of 1: 50,000 is probable sufficiently strong to destroy most algae. It is an interesting fact that the higher concentrations are re-

‡Communicated to the writer by Professor W. M. Barrows, Ohio State University.

quired for many of the ephemerals, noted above (*e. g.*, Volvox, Scenedesmus), and for those heavy walled algae (*e. g.*,Cladophora, Pithophora, some Oedogoniums) whose peripheral coating contains substances resembling chitin. In the former case the stronger solution is doubtless required, more because of the rapid growth and formation of new individuals than because of any particular resistance to copper. In the larger algae the difficulty of diffusion of the copper through the chitinous periphery seems to account, in part at least, for the necessity of the higher concentrations.

Water containing such qualities of copper sulphate as noted above is not injurious for human consumption. It is, therefore, a relatively simple matter to rid a pond or reservoir of obnoxious algae by the application of copper sulphate. The practical method usually recommended is to row a boat, to which is tied a gunny sack containing blue vitriol, several times through the pond, allowing for the gradual solution of the $CuSO_4$ into the water.

If the pond or reservoir is also a fish pond, other precautions are necessary. Concentrations of $CuSO_4$ are detrimental to young fishes in varying degrees, some fishes being much more susceptible than others. To take a single example: Moore and Kellerman [11] list young black bass as being able to withstand without injury concentrations of $CuSO_4$ some thirteen times as great as young trout.

The presence along the seashore of large quantities of "sealettuce" (species of Ulva) is responsible for obnoxious odors coming from these decayed plants.

Economic Aspects: Beneficial.

1. Source of Potash.

Before the World War much of our supply of potash came from Germany. This supply was not available during the war and we began to investigate other sources, of our own. Attention was early turned to the kelps, brown algae of the Pacific Coast. It was found that species of Macrocystis, Nereocystis, and Pelagophycus contained a considerable amount of potash in the form of potassium chloride, percentages as high as 30% dry weight being reported. Potash can be secured from deposits in our own west and southwest and this is more economically secured than from the kelps. It should not be forgotten, however, that these brown algae represent rather vast areas which are available for potassium salts.

2. Source of Iodine.

It has long been known that many of the marine algae contain iodine. Iodine of course occurs sparingly as iodines and iodates of potassium and sodium, and it is found in mineral springs, salt water, and in the mother liquids obtained from the purification of Chile salt-petre. According to Burd[2] some species of brown algae, like Macrocystis contain in the blades as much as 0.29% iodine; Pelagophycus, 0.38%; Nereocystis, 0.14%; and entire plants of Laminaria 0.49% (all dry weight computations).

The presence of iodine in many of the red algae is probably of little importance economically because of their lack of bulk. An interesting controversy exists among some of our European algologists as to the presence of free iodine in some of the red algae. It has been reported positively in a species of Falkenbergia by Sauvageau.[13]

3. Deposits of Travertine.

Emig[4] reports many species of algae as being concerned in the formation of travertine. Banded travertine, consisting of parallel layers of calcium carbonate, if treated with dilute hydrochloric acid, will yield filamentous and unicellular algae "that retain in general the outward form of the original mass" (Emig, *loc. cit.*). These algae were largely, in the Oklahoma travertine, species of Oscillatoria and Lyngbya and unicellular Chlorophyceae.

Recently formed cavernous travertine, not of such uniform structure as the banded form, contains in an identifiable condition filaments of *Vaucheria geminata* (Vauch.) DC. and *V. sessilis* (Vauch.) DC., together with species of Oscillatoria, Lyngbya, Rivularia, Trochiscia, Oedogonium, Cladophora, and Batrachospermum.

4. Direct Fertilizers.

Farmers near the seashore have probably used the large marine algae as direct fertilizer for many years. Soldiers unfamiliar with this practice were much impressed during the World War with the thriftiness of French peasants in bringing in quantities of "seaweed," scattering it over their farms, and allowing it to decay or plowing it under. Similar practices have been known from the eastern coast of Asia, Japan, parts of South America, and our own New England and Eastern Canada. Of course nothing new is involved here: merely adding to the fertility of the soil by providing complex compounds to be oxidized and broken down by soil microörganisms into simpler compounds, that can be used by the growing crop.

5. *Aids in Landscape Improvement.*

To those who are accustomed to think of landscapes in terms of forests, ornamental plantings, grasslands, or waving fields of grain, the place occupied by the algae in the scheme of improvement will seem relatively small, if not entirely negligible. In many respects this is true. The various colors one sees on exposed cliffs, rocks, and stones are often due to the growth of some lichen, whose food-making, chlorophyllous constituent is an alga. In extremely arid regions where a mere smattering of rain occurs once a year, one of the reliefs from the monotony of grayness and sameness is the sudden though temporary appearance of "green soil"; *i. e.*, soil algae which have come into being again with the increase of moisture.

The subaerial algae of the tropics constitute a very important element in the appearance of the landscape. Due to the excessive heat and moisture, growth of all plants is most luxuriant, and one finds algae occupying the trunks of trees, rocks, soil, and even the green foliage of flowering plants. Fritsch[6] has been so impressed with the scenic effect of the bluegreens in the tropics that he has been able to note four types of subaerial forms, readily distinguished by their general aspects, *viz.*, adhesive, tangled, tufted, and stratified, The same author notes rather definite orders of successions of various algae in the "colonization of new ground."

6. *Soil Algae.*

In the immediately preceding paragraphs attention has been called to the importance of some soil algae in scenic effects. There are numerous species of algae occupying various depths of soil. The more numerous forms are near the surface, but some extend to a depth of forty feet or more. The spores of many soil algae are able to withstand remarkable desiccation without losing viability. Mrs. Roach[2] found in an examination of soils from Rothamstead that the spores of certain bluegreens were viable after a period of over sixty years.

From an ecological standpoint it is interesting to watch the development of Marchantia in greenhouse beds when special effort is not made to combat the bluegreens. The liverworts flourish for a season but in time the upper surface of the soil becomes increasingly bluegreen and finally the liverwort must be started all over again. The bluegreens are thus able to compete successfully with the Marchantia.

It is difficult to estimate the value of soil algae in helping to maintain fertility, because of the lack of any quantitative data. The fact of their prolific growth at the surface in favorable environments and their large numbers even below the surface must mean considerable, in the aggregate of their contribution to the organic composition of the soil.

7. Useful Organisms for Research.

It seems fitting to note here very briefly the place of algae in programs of research. Attention is given later to the importance of the algae as aquatic organisms. Algae are usually present in bodies of water available to any investigator. Many forms may be successfully grown in cultures, their anatomical and structural features are relatively simple—a single cell is often an organism—large numbers of individuals are present simultaneously, and several generations may be secured in a relatively short time. In studies involving microchemical analyses of cell walls and protoplasts, in investigations upon the influence of intensity and quality of light on plant growth, in determinations of hydrogen ion concentration *in situ*, in ascertaining the role of mineral elements in plant metabolism, and even in cytological and genetical work, the algae are very much worthwhile as "subjects" for research. They have been utilized considerably in the past and they might very well receive additional consideration in the future.

8. Direct Source of Food for Man.

The angle of inclination of the average civilized nose changes perceptibly at the very mention of "pond scums," "green slime," or "frog spit" as food. Words and images are, however, sometimes merely synonymous with our prejudices. A well-known Ohio newspaper editor, for instance, is moved to write columns and columns of the bitterest paragraphic irony at the mere mention of the word spinach. Dietitians, on the other hand, are wont to recommend spinach as "strength to the weak and meat to the hungry." Difference in point of view? Prejudice vs. facts? Perhaps.

In the first place it should be recalled that algae are green plants and that their fundamental processes of food manufacture are similar, if not identical, with those of any other chlorophyll-bearing organisms. As a result of their food syntheses and assimilative processes we have proteins, fats, carbohydrates, cell walls, protoplasm. A corn plant could hardly do more.

It is a matter of rather common knowledge, I suppose, that

many of the marine red and brown algae and a few genera of greens are not an inconsiderable item in the food of the oriental. According to West[18] species of the larger Spirogyras are dried and sold in the markets of Upper Burma. In Hawaii species of Enteromorpha and of Ulva called "Limu eleele" and "Limu pahapaha" respectively, are used as food. In Brazil and probably in other South American countries flat colonies of Nostoc (*N. communis?*) are gathered, boiled, and thus used as food.

9. Sources of Food and Energy—Indirect.

If we refuse to be impressed with algae as direct sources of food for mankind—and no penalties are provided for such obstinancy—we may very profitably consider these aquatic plants as indirect sources of food and energy.

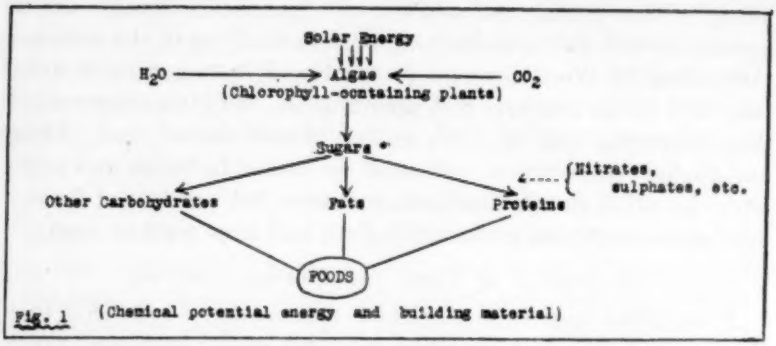
Whatever may be the expression one cares to use to define the algae, it will suffice here to regard them as chlorophyll-bearing plants†. As such, they are capable of photosynthetic activity. Given the proper environmental conditions conducive to an adequacy of solar energy, raw materials, and proper temperature, algae manufacture *food:* carbohydrates, fats, and proteins. The food so formed is the sole source of building material and energy needed for the growth of the plant. (See Fig. 1.)

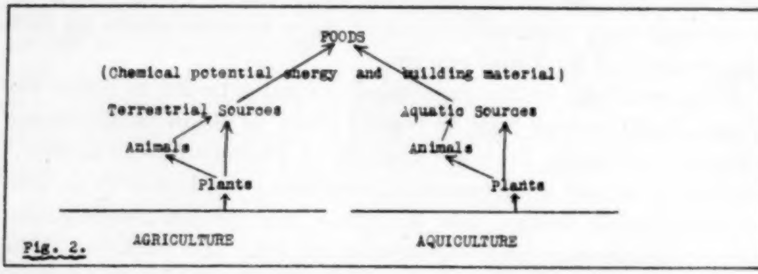
The potentiality of synthesizing carbohydrates, fats, and proteins from raw materials of the environment is the peculiar property of green plants. It becomes an aphorism, therefore, to say that green plants are directly or indirectly the sole source of the world's food supply.

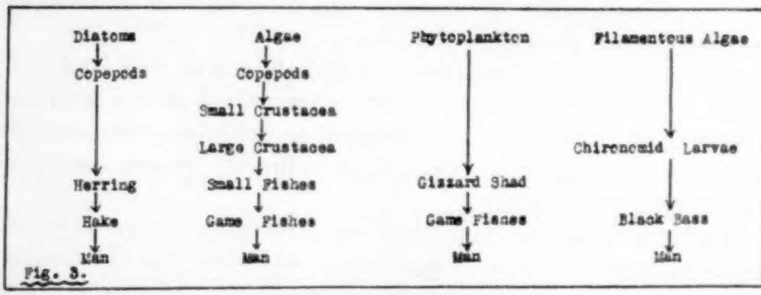
The terrestrial sources of food are universally known to be associated, more or less, with agriculture, an industry as old as man. The food of man has always come from plant and animal products, and the latter have been possible only because of the former. It is a fact specifically then that the terrestrial sources of all food and energy directly or indirectly are plants. (See Fig. 2.)

Suppose that we consider similarly the aquatic plants. Of the latter the algae alone can be considered within the scope of this paper. It will be recalled that in a preceding paragraph mention was made of the occurrence of definite periodicities among the algae. If we examine those algae which Transeau has termed ephemerals (Cf. Fig. 4), *i. e.* forms with an individual life history of short duration, and yet as a group continuously present in bodies of water throughout the growing season, we are aware of

†Some forms of algae have the green color much modified by other pigments, and a few are colorless.







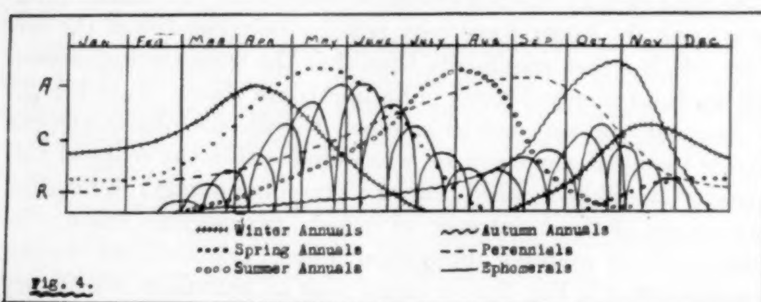


Fig. 1. Diagrammatic representation of algae and their energy relations. (*Sugars may not be the first goods formed in all algae, apparently, but serve to indicate the food and energy relations.)

Fig. 2. Diagrammatic representation of terrestrial and aquatic food resources.

Fig. 3. Some illustrative food cycles of aquatic organisms.

Fig. 4. Diagrammatic representation by months of algal periodicity. A = Abundant, C = Common, R = Rare. (After Transeau.)

an enormous "turnover" in "crop." This crop in effect serves as an almost continuous harvest for the myriads of microscopic and often macroscopic animals inhabiting the bodies of water. The larger aquatic animals (like the adult fishes) may feed upon other animal organisms, which in turn have had to depend upon the plants. We have the aquatic food and energy supplies, as in the terrestrial, directly or indirectly depending upon plants. The industry concerned with developing aquatic resources has been termed aquiculture. (See Fig. 2.)

As concrete examples of the dependence of aquatic animals upon aquatic plants, attention is called to some previously worked-out food cycles (see Fig. 3). Perhaps a common cycle is represented in the circuitous route from algae through copepods, small and large crustacea, small fishes, big fishes, and eventually man. Only one point needs emphasis here: The longer the cycle, the more food and energy consumed by the intermediaries and correspondingly less of the original energy value available for man.

Another chain of events with fewer links is that involving the gizzard shad[14, 15, 16]. Mann[8] in working with marine organisms reaches the succinct conclusion: no diatoms, no hake. Moore[9] has worked out another cycle in which the baseball classic "Tinkers to Evers to Chance" becomes biologically "filamentous algae to chironomid larvae to black bass."

It is thus seen from the few above mentioned examples—and their actual number is doubtless legion—that aquatic plants have a real potential value for mankind in terms of food and energy.

It might be well to supplement these few cases with some statistical data of a slightly different sort. Granting for the nonce that the total inland water area of the state of Ohio, which is estimated at some 200,000 acres, is potential "soil" for algae and fishes, we should be able annually to "harvest" some 28,000,000 pounds of fish with an estimated energy value of 14,000,000,000 Calories. A very conservative estimate of the crop of algae for a single year (one must keep in mind the periodicities and turnovers) from these same waters is 1,152,000,000 pounds. If an acre of algae is equal in calorie efficiency to an acre of corn, this Ohio crop would yield the enormous energy output of about 345,000,000,000 Calories. The figures are the merest approximations, of course, but if we could conserve the algae and use them as food, we have the startling amount just noted; if the

algae must be used by the fishes which in turn yield food to man, we have only 14,000,000,000 Calories: the ratio 345: 14, or nearly 25:1 is rather significant.

We may perhaps never be interested in aquiculture as an industry which is concerned alone with the cultivation of algae. We must be interested, however, in any phase of an industry that adds to the sum total of the world's energy supply. Whether it be the cultivation of more diatoms for marine fishes or the growing of pond algae for inland fish propogation or the introduction of fishes like the gizzard shad[14] to cut down the length of the food cycle before reaching man, it should not be forgotten that the organic genesis of all this aquatic energy, the than-without-which-nothing, is the alga. It should be remembered further that this vast accumulation of energy is scarcely touched, as yet, in terms of human consumption.

In the presentation of much data there often arises confusion. Certain of our rather much perturbed "testing" psychologists have been declared to be able to add peaches and plums and pears and divide by cherries and get tomatoes[1]. It is to be hoped that the conclusions regarding the economic importance of the algae are not considered as having been reached in the same way. It might not be too much, then, to ask that when we think of algae as "pond scums" or "frog spit" or "that awful moss" (whether appropriate or not), we might also associate the facts of water contamination, of sources of iodine, potash, and soil fertility, of useful subjects of research, and sources of food and energy directly or indirectly for the human race.

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AMERICAN PUPILS ARE TWO YEARS BEHIND.

Because they are not admitted to the high school until they have completed eight grades, pupils in the United States and Canada are held at a rudimentary level for a longer period than are the pupils of any other civilized country. They are, as a result, two years behind European pupils in securing the education which is necessary for admission to the professions and to the higher levels of commercial and industrial training.

It can be asserted without fear of contradiction that 12-year-old pupils in American schools are often studying complicated and artificial methods of solving arithmetic problems when they should be using the methods of advanced mathematics. They are reviewing geography when they ought to be acquiring knowledge of international economic and social relations. They are reading orally when they ought to be gaining a mastery of literature. In short, they are treated as intellectually immature, as incompetent to deal with subjects which can be demonstrated by relatively easy experiments to be stimulating to them and to be well within their powers of comprehension.—Extract from the "Report of the Commission on Length of Elementary Education" in *School Life.*

SABBATICAL LEAVE.

W. F. Webster, Superintendent of Schools in Minneapolis, in an article on "Considering the Benefits of Sabbatical Leave" in *The Nation's Schools* quotes some interesting data furnished by the N. E. A. Research Division. Thirty cities grant sabbatical leave. The rules for carrying on a sabbatical leave are nearly uniform for all cities. There must first be a period of service before leave can be secured. Twelve cities demand seven years of prior service and thirteen call for ten years. One city demands six years, one eight, one fifteen, and one, Richmond, Virginia, asks for but three years. The length of the leave is one year or one-half year, twenty-two cities granting a full year, and eight one-half year. Fifteen cities give half pay, while three give full salary less the pay of a substitute. Seven cities limit the pay to $1000 or some other fixed amount. As to the reasons for sabbatical leave, Mr. Webster sums up his ideas in a sentence—"A sabbatical leave should be granted for rest, for study, for travel—these three—but for today, the greatest of these is travel."

THE ELECTRON THEORY APPLIED TO VALENCE AND THE FORMATION OF COMPOUNDS.

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PROOF OF THE EXISTENCE OF THE ELECTRON.

We are indebted to J. J. Thompson, Lenard, Kauffmann, Millikan, and others for our information concerning the electron. In an article published in the Philosophical Magazine (1897) Thompson outlined the results of several experiments which indicated the existence of the electron and some of its characteristic properties. Briefly these experiments were: A highly evacuated tube, equipped with electrodes, was connected to the terminals of an induction coil. When the current was turned on there was projected from the cathode tiny particles of matter which have since been known under the following names; Electrons, Negative Rays, and Cathode Rays. By experimentation with cathodes of platinum, iron and aluminum, it was shown that the electrons were projected from the cathode regardless of the material composing it. Apparently any conducting material can be used for the cathode and the results will be the same. That the electrons carry a negative charge was proven by their attraction by a positive electrostatic field and their repulsion by a negative electrostatic field. Repulsion and attraction by magnetic fields was also shown. This latter phenomena is best shown by allowing a stream of electrons to impinge on the surface of a zinc sulfide screen. A phosphorescence marks the path of the electrons and shows, by its bending, the attraction or repulsion exerted on the electrons. That the electrons are made of ponderable matter can be shown by allowing the stream (of electrons) to strike the vanes of a small paddle wheel mounted on a track placed in the cathode tube. The bombardment of the electrons causes the wheel to rotate and travel along the track. This type of tube is known as the railway tube. That the electrons carry considerable energy, which may be transformed into heat, may be demonstrated by focusing the electrons (using a concave cathode, since the rays cannot be focussed in any other fashion) on a platinum shield. The heat produced will under good conditions melt thin platinum foil.

Lenard has proved the extreme smallness of the electron by passing them thru a window located at the end of the tube opposite the cathode. This window was made very small in

order to withstand atmospheric pressure and of aluminum foil to allow the passage of the electrons. Recently Coolidge has perfected a larger tube with large window. Some very interesting results have been obtained with this larger apparatus. Evidently the electrons must be of subatomic proportions in order to pass through these windows without affecting the vacuum.

J. J. Thompson proved that the electrons carry negative charges by causing the electron stream to fall upon a plate connected to an electroscope. A pronounced divergence of the leaves proved that the electrons carried an electrical charge. That this charge was negative was proven by the collapse of the leaves of the electroscope on attachment to a source of positive potential.

The mass of the electron is about 1/1840 that of the hydrogen atom. Millikan's research has shown us that the electron is the atom of electricity carrying a definite electrostatic charge. An excellent account of this work may be found in Millikan's—The Electron, University of Chicago Press.

Our most recent theories lead us to believe that the electron is an integral part of every atom. We now conceive of the atom as being made up of equal numbers of electrons and positive charges. The positive charges we call protons. According to this conception the hydrogen atom is made up of one proton (mass 1.0078) and one electron. Helium atoms are made up of four protons and four electrons. We may note that four times the weight of the proton gives a result larger than the atomic weight of helium. This has been explained on the basis of a so-called "packing effect" which results in the loss of mass due to the energy of attraction of the electrons and protons. Spurgin's description (School Science and Mathematics, March 1922.) is very excellent and for that reason further reference to atomic structures is omitted in this article.

Classes of Atoms.

Under the electron theory it is convenient to divide atoms into four classes based upon their behavior in combining with other atoms (or not combining). Atoms tend to become most stable when combined with other atoms, or we may say that they tend to become more stable by the loss or gain of electrons. As will presently be seen this is not entirely true.

Class I.—Atoms which do not gain or lose electrons. The rare

gases are classed in this group. Inasmuch as electrons must be gained or lost before chemical action can result and chemical union be brought about, we shall expect atoms in this class not to enter into chemical combinations. This is in strict accord with all of the chemical properties of the rarer gases.

Class II.—Atoms which lose one or more electrons. Most metals belong to this group. Some nonmetals may be classified here also. The loss of the electron or electrons is accompanied by union with some other atom or atoms. This leaves the atom with an excess positive charge (since all atoms in the neutral state have equal numbers of protons and electrons and the loss of electrons leaves an excess of protons) or charges numerically equal to the number of electrons lost. Examples:

Na loses 1 e forming Na^{+}
Fe loses 2 e forming Fe^{++}
Al loses 3 e forming Al^{+++}

Class III.—Atoms which tend to gain electrons. Fluorine is apparently the only member of this class.

F gains 1 e forming F^{-}

The addition of the electron gives the atom one excess negative charge. Oxygen might be placed in this group except for its structure in hydrogen peroxide.

$$\overset{+}{H}\ \overset{-+}{O}\ \overset{--}{O}\ \overset{+}{H}$$

Oxygen in this case, in one instance at least, has lost one electron and gained one electron. Due to valence requirements there is no neutralization of an intra-atomic type. The other atom of oxygen has behaved in the normal fashion with the gain of two electrons.

Class IV.—Atoms which may under different conditions gain or lose electrons. The greater number of elements is classified in this group.

Examples:

C loses 4 e forming C^{4+} as in CO_2
C gains 4 e forming C^{4-} as in CH_4
S loses 6 e forming S^{6+} as in SO_3
S gains 2 e forming S^{2-} as in H_2S
Cl loses 7 e forming Cl^{7+} as in $KClO_4$
Cl gains 1 e forming C^{1-} as in KCl
N loses 5 e forming N^{5+} as in HNO_3
N gains 3 e forming N^{3-} as in NH_3

A strict interpretation of the development of valence in the case of carbon is not in accord with the system here developed.

We should refer it to the pairing of electrons rather than to an actual loss or gain of electrons. There is however no inherent difficulty since the loss or gain of one electron is equivalent numerically to the formation of one pair of electrons. In the above examples it is well to note that the sum of the electrons gained and lost is eight. Apparently the most stable configuration of the electrons in the outer shell or system of orbits is eight. There is likewise the tendency for all atoms to gain electrons until eight are present or lose until the next complete inner shell or system of orbit is reached.

TABLE OF VALENCES.

Mono-valent.		Di-valent.	
Positive.	Negative.	Positive.	Negative.
H	Cl	Ca	S
Na	OH	Ba	O
K	NO_3	Mg	SO_4
Ag		Zn	CO_3
NH_4		Hg	
		Cu	
		Fe	
		Sn	
		C	

Tri-valent.		Tetra-valent.	
Positive.	Negative.	Postive.	Negative.
Al		Sn	
Bi		C	
Sb	Sb	Si	
Fe		S	
P	P		
N	N		
As	As		
	PO_4		

Penta-valent.
Postive.
N
P
As
Sb
Bi

Sulfur has a valence of six not mentioned above, while chlorine has a positive valence of five and seven.

The Electron and Valence.

It has been noted that there is a tendency for the atoms either to gain or lose electrons in all cases excepting the chemically inactive elements. Such tendencies must be very closely related to valence. We notice that sodium with a valence of one loses one electron; calcium with a valence of two loses two electrons; aluminum with a valence of three loses three electrons. In all cases of so-called positive valence there is a loss of electrons numerically equal to the valence developed. Negative valence may be explained on the basis of gain of electrons. Fluorine with a valence of one gains one electron; oxygen with a valence of two gains two electrons; nitrogen with a valence of three gains three electrons. In each case there is a significant parallelism between the number of electrons gained and the valence developed. In all cases of negative valence there is a gain of electrons. In conclusion we may say that the gain or the loss of electrons must in some way be very intimately connected with valence and may be the cause of valence. The writer is inclined to the latter view.

It is necessary before applying the electron theory to valence to reclassify the valence table. The table listed above is taken from a standard high school text (Black & Conant—Practical Chemistry). The elements have been grouped under the older headings with subdivisions of positive and negative valences. Positive—electrons lost. Negative—electrons gained.

Formation of Compounds.

Whenever an atom tending to lose one electron is brought in contract with an atom tending to gain one electron, there will be formed a chemical compound. For example:—sodium will lose one electron and chlorine will gain one electron, therefor there will be formed sodium chloride, in which the sodium is positive and the chlorine negative, because of the passage of one electron from the sodium to the chlorine. The actual transfer of electrons can be demonstrated by a suitable arrangement of the gas electrode and the sodium electrode. Assuming that the above is representative, the formation of several typical compounds may be represented as follows:

A mono-valent metal with mono-valent, di-valent, or tri-valent non-metals or acid radicals.

Na loses 1 e
Cl gains 1 e forming NaCl.

One sodium will supply the necessary one electron for the chlorine.

Na loses 1 e
SO_4 gains 2 e forming Na_2SO_4.

There must be two sodium atoms present in order to supply the two electrons for the sulfate radical. Under a strict interpretation of the electron theory, the valid objection may be raised, that the sulfate radical has its full complement of electrons as evidenced by its negative charges. Moreover the sodium would not join the sulfate radical until it had lost an electron. The sulfate radical must at some time have acquired the two electrons from some metal. Since the sulfate radical does not exist free from combinations the only way in which it can unite with sodium is during a complex reaction in which the sodium exists in the ionic state (has lost its electron) and the sulfate radical is present in a like condition. Under these conditions the sodium sulfate will be formed as the result of the union of the sodium and the sulfate ions.

Na loses 1 e
PO_4 gains 3 e forming Na_3PO_4.

Bi-valent metals with the above combinations.

Zn loses 2 e
Cl gains 1 e forming $ZnCl_2$.

Two atoms of Chlorine are required to take up the two electrons liberated by the zinc.

Zn loses 2 e
SO_4 gains 2 e forming $ZnSO_4$.

One sulfate is equivalent to the one zinc ion.

Zn loses 2 e
PO_4 gains 3 e forming $Zn_3(PO_4)_2$.

Since the loss and the gain of electrons are for these atoms, the least number of atoms of each must be taken which will result in the loss of electrons being equal to the gain of electrons. Three zinc atoms will in all lose six electrons, while it will require 2 phosphate radicals to be equal to the six positive charges developed.

Tri-valent metals with the above combinations.

Al loses 3 e
Cl gains 1 e forming $AlCl_3$.

It will require three chlorine atoms to take up the electrons lost by the aluminum.

Al loses 3 e
SO_4 gains 2e forming $Al_2(SO_4)_3$

It is here necessary to treat this combination in the same manner as in the case of the zinc and phosphate radical.

Al loses 3 e
PO_4 gains 3 e forming $AlPO_4$.

Variable Valence.

Sulfur has a valence of two, four, and six, the latter two being positive. Sulfur with a valence of two tends to gain two electrons. These two electrons must be supplied by an element having a positive valence. Examples:

S gains 2 e
H loses 1 e forming H_2S.

S gains 2 e
Zn loses 2 e forming ZnS.

Sulfur has a positive valence of four. It must therefor unite in this condition with an element having a negative valence.

S loses 4 e
O gains 2 e forming SO_2.

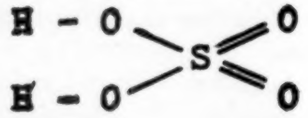
With a valence of six, sulfur forms with oxygen, sulfur trioxide.

S loses 6 e
O gains 2 e forming SO_3.

The proper application of the electron theory to valence will result not only in the derivation of the correct formulas, but will predict possible combinations. Elements possessing positive valence will unite with elements possessing negative valence. Positive elements will not unite with positive elements, neither will negative elements units with negative elements. Several exceptions to this are only apparent and not real. They are simply instances in which an element may be either negative or positive. This negativity or positivity is determined by the combination with other elements.

Structural Formulas.

We have heretofore written our structural formulas in a certain accepted fashion without fully explaining why. Even with the help of the electron theory there still exists considerable doubt as to certain formulas. Sulfuric acid has been written:



Apparently this is the only structure which will satisfy many of the properties associated with sulfuric acid. It is imperfect in that it does not show the existence of the complex sulfate radical or the difference in the degree of the ionization of the two hydrogens. The above arrangement, if we concede that it is representative, must be intimately connected with the electrical charges on the atoms composing the molecule. Writing the structural formula to show these electrical charges, we have:

$$\begin{array}{lll}
\mathrm{H}^{+\,-}\mathrm{O}^{-}+ & & {}^{+}{=}\mathrm{O} \\
 & \mathrm{S}^{+}_{+} & {}^{-}\mathrm{O} \\
\mathrm{H}^{+\,-}\mathrm{O}^{-}+ & & {}^{+-}
\end{array}$$

Hydrogen must be united to sulfur thru the oxygen. Hydrogen can make use of but one of the bonds on the oxygen. The oxygen is not apt to unite to other oxygen atoms, hence the presumption of the union with the sulfur, with the residual oxygen attached thru double bonds to the sulfur. These bonds may be interpreted as the hydrogen giving up electrons to the oxygen, accounting for one charge on each oxygen, of those connecting the hydrogen to the sulfur. The other electron on each oxygen is derived from the sulfur, accounting for two of the positive charges on the sulfur and for the negative charge on each oxygen. Two electrons are lost to each of the two oxygen atoms thus accounting for the two negative charges of the oxygen and the development of the four positive charges on the sulfur.

It is to be noted that the formula consists of alternate rows of negatively and positively charged atoms. The sulfur constitutes a positive column leaving the two oxygen atoms to fill in the last negative column. In dividing the formula into positive and negative columns, we have:

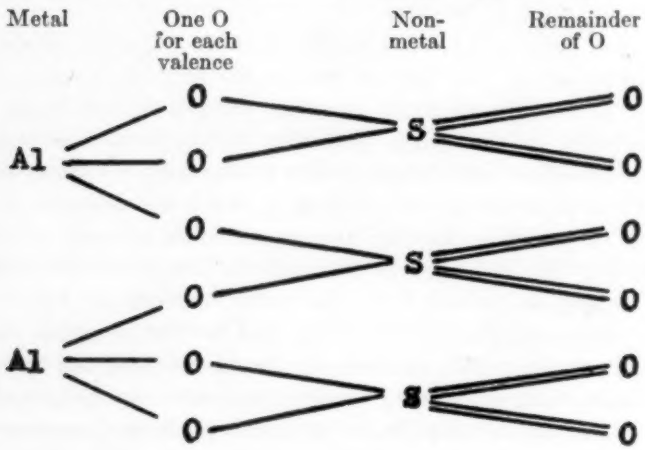
$$\begin{array}{cccc}
+ & - & + & - \\
\mathrm{H} & \mathrm{O} & & \mathrm{O} \\
 & & \mathrm{S} & \\
\mathrm{H} & \mathrm{O} & & \mathrm{O}
\end{array}$$

In the first column, we have all of the metal joined to the oxygen in the second column with the sulfur in the third column joined to the oxygen of the second column. In the fourth column the remainder of the oxygen atoms is placed, being joined to the sulfur by two bonds each.

We may apply the above (with a few modifications) to the writing of many structural formulas. In the first column all

of the metal or that which takes its place, will be located with a bond for each valence. In the second column one oxygen atom is connected to each bond from the metal. The other oxygen bond is connected to the non-metallic atom or atoms, the latter being placed in the third column. In the fourth column, the remainder of the oxygen is placed and joined to the non-metallic atom or atoms by two bonds for each oxygen atom. When writing a formula, four vertical columns are drawn, and the above procedure followed.

Structural Formula for Aluminum Sulfate.



Now connect with bonds as indicated. The formula for aluminum sulfate is rather difficult to write under ordinary conditions. However with the aid of the above method it becomes less difficult.

The writer has used the following method in High School classes. This method is but a modification of the material outlined above. To derive the empirical and structural formulas for zinc phosphate.

This is a combination of Zn and PO_4. Zinc loses two electrons while the PO_4 gains three electrons.

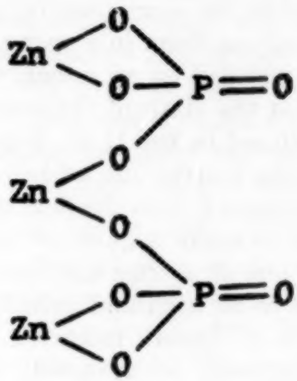
Zn loses 2 e

PO_4 gains 3 e

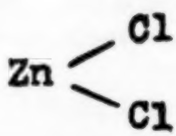
In order to have the chemical compound formed, the number of electrons gained by the phosphate radical must be equal to the number lost by the zinc. This condition may be satisfied by taking three atoms of zinc and two phosphate radicals, giving:

3 Zn lose 6 e
2 PO_4 gain 6 e forming $Zn_3(PO_4)_2$.

The structural formula is written in the manner outlined above.



In writing the structural formulas for compounds which do not have oxygen present, the above plan is followed, but since there is no oxygen the second and the last columns are eliminated resulting in the direct joining of the metal and the non-metal. In forming zinc chloride.



In the opinion of the writer, the foregoing material greatly simplifies the teaching of valence, formation of compounds, and the determination of the correct formulas, both empirical and structural. Experience in the teaching of beginners in chemistry, using both the older methods of teaching valence and this newer method, has demonstrated the usefulness of the latter. The writer makes no claims to originality in this matter, altho a great deal of the method was developed and used six years ago.

Irrationally held truths may be more harmful than reasoned errors.—*Thomas Henry Huxley in "The Coming Age of the Origin of the Species."*

HOST.

By Walter H. Carnahan,
Shortridge High School, Indianapolis, Ind.

Some years ago the writer's interest in mathematics, mathematics clubs and games of skill resulted in the suggestion to take some of the more familiar geometrical plane and solid figures and use them in a game. If this interest in games must be justified by an appeal to the authorities let me point out that the sixth of the seven principal aims in education as outlined in the U. S. Bureau of Education Bulletin No. 55 is the worthy use of leisure. If Host has any contribution to make it is in the field of this aim. After the first suggestion to make a game of geometrical figures ideas accumulated one at a time and about five years ago selection of figures to be used and principles of play to be observed was made at leisure moments. The figures selected were tetrahedrons, or pyramids, cubes, hexagonal prisms, cylinders, spheres, triangles, squares, hexagons, and circles. These figures were made of wood and mounted on turned bases. Solitaire games served to perfect the rules of play and revealed new possibilities of the game. Friends who learned the game contributed suggestions which resulted in improvements. After numerous revisions the rules now stand as given below. Pieces for the game are not marketed but can be made with a few tools without much expenditure of time.

The name HOST* was derived by taking the initial letters of the words hexagon, square and triangle and for the "O" using a small circle which is often used as a symbol to represent a circle.

Before quoting the rules it may not be out of place to suggest a few principles of play observance of which will tend to give the game something of systematic procedure and bring out the power of the pieces. In general it seems best to advance the solids first and bring out the planes to support them. This means that a number of the early moves will be made by jumping. As soon as possible make direct attack upon the opponent's sphere and thus put him on the defensive. Post the attacking piece so as to make

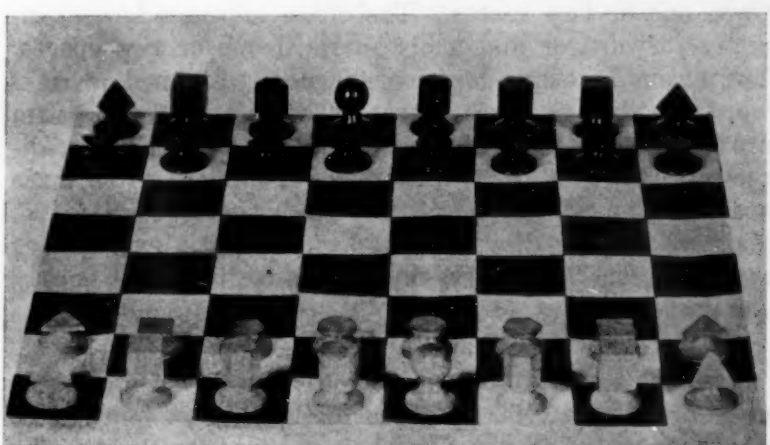
double attack upon the sphere or "fork" the sphere and some other valuable piece if possible: this will often force the opponent to discard a plane piece. The best first move is probably to post the cylinder at the sphere's prism's third space. On the second move one can then place the cylinder so as to force a discard. In defending by interposing a solid bring out a piece not previously moved if possible; this will have the obvious effect of getting more pieces out where they can be effectively used in play. Attack a stronger piece with a weaker piece and thus get an advantage out of the exchange. A little experience will suggest other principles that will give the game system and purpose.

Rules for Playing Host.

Host is played by two players on the ordinary checker board. Each player has eight solids and eight planes. The pieces of one player are black and of the other white. Each player has two pyramids (regular tetrahedrons), two cubes, two hegagonal prisms, a sphere, a cylinder, two triangles, two squares, two hexagons, and two circles.

Setting up the Pieces.

In the first row each player places his solids. At the extreme right and left are the pyramids; in the spaces next these are the cubes, then the prisms, then the sphere and cylinder, these being so placed that the sphere is at the right of the cylinder. In the second row are placed the planes,



Host Pieces Properly Set up Ready for Play.

each being so placed that it stands before a solid of which it represents a cross section. At the right and left are the triangles, then the squares, then the hexagons, then the circles.

The Moves.

Unless otherwise agreed, white moves first. If the pieces are placed upon the board with a straight side of each (except of course the sphere, cylinder and circles) extending right and left the shape will suggest the general direction in which any piece may move. This is merely a convenience in learning the moves and there is no rule to compel a player to so place his pieces. As indicated by the arrows in the accompanying figures the triangle moves sidewise right or left one or two spaces, or it may move on a diagonal forward one or two spaces. It may never move

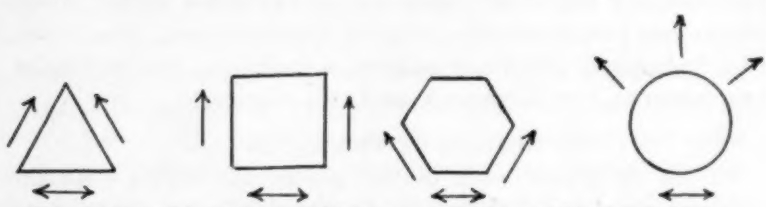


Diagram to Indicate the Moves of the Plane Pieces in Host.

backward. The moves of the hexagon are the same as those of the triangle. The square moves sidewise or forward one or two spaces. The circle moves sidewise, directly forward or diagonally forward one or two spaces. The pyramid moves sidewise or diagonally forward or backward one, two or three spaces. The moves of the prism are the same as those of the pyramid. The cube moves directly forward or backward or sidewise one, two or three spaces. The cylinder moves directly forward or backward, diagonally forward or backward, or sidewise, one, two or three spaces. The sphere moves in any direction but only one space.

Jumping.

Any solid except the sphere may jump over any plane piece of its own color provided neither the jumping piece nor the piece to be jumped has been moved previously. The solid must come to a stop in the space just beyond the piece

jumped unless it captures a plane there and goes on to capture another piece.

Capture of Pieces.

A piece is captured by moving into the space which it occupies. A plane may capture one or two pieces at a time but must stop whenever it captures a solid. That is, if the first piece captured is a solid it may not go on to capture a second piece, but if it first captures a plane it may go on to capture any piece within range. A solid may capture one, two or three pieces provided it must stop whenever it captures a solid. A player is not compelled to capture a piece if he prefers not to do so. Or, he may capture one piece and stop although it would be possible for him to go on and capture a second or third piece. When one piece is captured the capturing piece need not go on in a straight line to capture a second or third piece but may turn and proceed in any direction permitted in the rule governing the moves of the capturing piece. The sphere may capture one, two or three pieces provided it does not have to pass over an unoccupied space.

Discarding.

Before moving a player may if he wishes discard one of his own plane pieces; that is, he may remove it from the board and then proceed to make his move.

The Object of the Game.

The object is to capture the opponent's sphere and the player who first does this is winner.

Exchange of Pieces.

When a plane piece reaches the opponent's row of solids it may be exchanged for the piece before which it stood when the game opened or for the other like solid. If neither of these solids has been captured the plane may be marked and used as a solid. If either circle reaches the row of solids it may be exchanged for a cylinder but not for a sphere. Exchange is not compulsory. If a player does not make the exchange when it is first possible he cannot exchange that plane at a later time.

WARNING.

When a player has any piece so situated as to threaten capture of his opponent's sphere he should give warning by calling "Host." However, there is no penalty for failure to give warning.

A SCALE FOR MEASURING ACHIEVEMENT IN GENERAL SCIENCE.

By August Dvorak,
University of Washington, Seattle.

Two recent references [1,2] to the General Science scale by the author,[3] have led him to conclude that information regarding this scale is not as common as had been assumed. For a complete report of the study which made this scale a necessity and for all the details of its construction the reader is referred to an earlier publication now available in monograph form from the publishers of the scale.[4] A brief discussion, however, of the Dvorak General Science Scale may be permissible at this time.

In 1921 the writer was a teacher of General Science in the University High School, University of Minnesota. In order to conduct a study of a number of phases of General Science achievement it was found necessary first to develop a test or scale of General Science achievement. It is to be remembered that in 1921 the available standardized tests in the science fields were few indeed, although work on several science tests now in print was then in progress.

The first step was to canvass the textbooks in General Science for General Science content. From a study of eighteen, then, latest texts in the subject it was found that about 600 facts or subdivisions seemed to cover the more common content. In reducing the 600 facts or ideas into objective test form it seemed that the multiple-choice type of statement with five choices for the correct response offered the greatest possibilities. It could be adapted to a majority of the facts or ideas, could be easily scored, and did not entail such ingenuity of construction as to

[1] Rich, Stephen C. "The available tests for results of teaching the sciences." SCHOOL SCIENCE AND MATHEMATICS. Vol. XXVI. No. 8. Pp. 845-852 (Nov. 1926).
[2] Cooprider, J. L. "A Reply—available science tests." SCHOOL SCIENCE AND MATHEMATICS. Vol. XXVII. Vol. No. 2. Pp. 195-197. (Feb., 1927).
[3] Dvorak, August. "General Science Scale." Public School Publishing Company, Bloomington, Ill.
[4] Dvorak, August. "A Study of Achievement and Subject Matter in General Science.' Public School Publishing Company, Bloomington, Ill.

be prohibitive. The donation by Earl R. Glenn and S. R. Powers of Teachers College of a number of items previously constructed for other purposes, and the loan of one hundred items or multiple choice statements by Professor G. M. Ruch of Iowa University facilitated the reduction of the 600 items of General Science achievement into multiple choice statements. In drawing up the final form of the three scales, certain items taken from the Ruch-Popenoe General Science Test, used in the statistical work, were left in the manuscript. The authors and World Book Company, publishers of the Ruch-Popenoe General Science Test, have kindly permitted us to retain these items. The 600 multiple choice statements made, however, so unwieldy a test that the number was reduced to 300. The selection was made on the principle of greatest frequency of inclusion in the eighteen textbooks and the apparent contribution to one or more of the "Seven Cardinal Principles of Education."[5] The resulting test had 300 multiple choice statements.

Twenty-two high schools in Minnesota took part in the experimental work, giving the 300 item test to all the pupils in the eighth grade and all the grades of the high school. Every kind of school was represented, from South High School in Minneapolis with over 3,000 pupils to a small high school of fifty or so pupils. In all, over 11,000 pupils performed on the original test.

The 300 item test was still so unwieldy and expensive in pupil and scoring time required that it was decided to construct a scale from the test data available. Since the scale was primarily to be used for eighth and ninth grade pupils, eighth and ninth grade pupils' tests were used to construct the scale. Since the first step of scale construction is the derivation of values of difficulty for each item, the frequency of correct responses was tabulated. When seventeen hundred pupils' tests had been tabulated it was found that increasing the number of tests tabulated did not vary the difficulty values of the items. The rank orders for the items secured on the basis of their difficulty from:

(a) 500 eighth grade girls and from 430 ninth grade girls gave rho $= .87 \pm .007$.

(b) 400 eighth grade boys and 430 ninth grade boys gave rho $= .916 \pm .005$.

[5]Cardinal Principles of Secondary Education. U. S. Bureau of Education Bulletin, 1918. No. 35.

(c) 500 eighth grade girls and from 400 eighth grade boys gave rho = .95 ± .003.

(d) 430 ninth grade girls and from 430 ninth grade boys gave rho = .91 ± .005.

Since 800 or 1,000 tests would have given the same difficulty values, 1,700 cases was enough for standardization. It is to be remembered that in the above correlations none of the eighth grade boys or girls had had the formal subject of General Science.

Having the frequency of correct responses for each item, these frequencies were reduced to percents of correct responses. These percents of correct responses were then converted into P. E. values of a normal distribution. The median item (in difficulty) for the ninth-grade pupils who had studied general science for one year was set at 8 P. E. or 80 units of one-tenth P. E. above an arbitrary zero point. All the items were then evaluated with reference to this arbitrary zero point. Each scale was made up of 60 items spread uniformly over a range of difficulty of 3 P. E. or 30 scale points of 0.1 P. E. each. These items were divided into three groups of twenty each. To make the scales more reliable, two items of equal difficulty were placed at each scale point or 0.1 P. E. level. The items were arranged in order of difficulty, the first two being easiest, the next two being 0.1 P. E. more difficult, the third two 0.2 P. E. more difficult, etc.

Thus each scale, made up of 60 items, has 30 levels of increasing difficulty, each level being 0.1 P. E. more difficult than the preceding level. Inasmuch as the final scores are computed in scale points of 0.1 P. E. each, this explains why in computing pupil's score (see manual of directions) two items done incorrectly are counted as one error. One error is equivalent to 0.1 P. E. of difficulty. Of the three forms of these scales, two (S-2 and T-2) are of equal difficulty and are so arranged that a score of 80 scale points (8 P. E. above zero) is the median score for ninth grade pupils who have just completed a year's work in general science. One form (R-1) is one P. E. less difficult, that is, a scale score of 90 is the median score for ninth year pupils just completing a year's course in general science. This form (R-1) is of especial value for diagnostic purposes at the beginning of the school year, particularly for classifying pupils into homogeneous sections for purposes of instruction.

The reliability of the three forms may be stated in several ways. First, 116 pupils who had completed their general

science course in the University High School were given the original 300-item test in June, 1922. The following September they were retested with the same test. The Pearson r for the two scores of 75 pupils on 300 items was .877±.02.

The Pearson r for the two scores of 116 pupils on the first 221 items of the test was .82±02.

Second, 140 pupils from the Stillwater High School were tested with forms S-2 and T-2 of the completed 60-item scale, as also were two groups of 24 and 34 pupils respectively from the University High School. The results follow:

Stillwater High School—140 cases. Forms S-2 and T-2-r= .70±.03.

University High School (a) 24 cases. Forms S-2 and T-2-r= .77±.05.

University High School (b) 34 cases. Forms S-2 and T-2-r= .71±.05.

Third, the probable error of estimation is about two scale points. With several groups of pupils it was found to vary from 1.1 to 2.5 points. A "P. E. of estimation" of 2 scale points is approximately correct for these scales. This is equivalent to saying that pupils taking one of these scales, on being retested with the same form or better still with another form of the scales, will in fifty percent of the cases secure scores varying not more than 2 points from their first score. An actual count of the differences between first and second scores made on S-2 and T-2 by about 200 pupils gave an average difference of 1.6 points. For most purposes this is sufficiently accurate.

Fourth, it was found that a majority of the pupils' responses were identical in two performances of the same test. There has been considerable discussion with regard to the amount of guessing pupils may do on an objective test of the multiple choice type. It is argued that when the pupil does not know the correct response he guesses and thereby increases his score unduly. Realizing that if this were true it would be possible for a pupil to take the 300 item test on two occasions, and make a score of 150 each time and yet not have a single item done correctly on *both* occasions. If this were true such a test would have a high reliability for the pupil because each pupil would make the same score on both occasions and yet such a test would be of no diagnostic value to the teacher, in that it would not show what material the pupil really knows.

Having the two 300-item tests for 116 University High School pupils, taken in June and September, 1922, which were discussed in the first experiment on "Reliability" above, an actual count of identical responses was made and reduced to percents of the total. Naturally the results varied with different pupils. One pupil had 98.1% of his items on the *second performance* either right or wrong respectively as he had them right or wrong on the *first performance*. The other extreme was 91.8% identical performance. The median for the 116 pupils was 95.65% identical performance. In other words from 1.9% to 8.2%, with a median of 4.35%, of the pupils' performances on the 300 items changed from September to June.

Measures of validity are more difficult to secure because of our lack of knowledge as to what are the real measures of a child's achievement. Hence the following are given as facts which may be measures of the validity of the scale.

For

140 cases r between Form S-2 scores & semester marks	.72 ±.03
140 cases r between Form T-2 scores & semester marks	.70 ±.03
140 cases r between (Ave. S-2 & T-2) scores & semester marks	.74 ±.03
24 cases r between Form S-2 scores & semester marks	.73 ±.06
24 cases r between Form T-2 scores & semester marks	.64 ±.08
24 cases r between (Ave. S-2 & T-2) scores & semester marks	.75 ±.06
34 cases r between Form S-2 scores & semester marks	.71 ±.06
34 cases r between Form T-2 scores & semester marks	.67 ±.07
34 cases r between (Ave. S-2 & T-2) scores & semester marks	.82 ±.04

Semester marks were given for the first semester absolutely without knowledge of the Scale Forms, and in the second semester before the Scale Forms were scored, hence independently of them.

For

28 cases r between 300 item test & marks	.83 ±.04
54 cases r between 221 item test & marks	.64 ±.05

For numbers of cases varying from 15 to 56 the r between the 300 item test scores or the 221 item test scores and five different intelligence test scores ranged from .43 to .73.

Some of the uses for which these scales are suitable are:

1. Measurement of individual pupil's achievement in general science in uniform numerical units so as to compare his achievement with that of other pupils, with that of his class or school, or with that of the thousands of pupils used to standardize these scales.

2. Measurement of the general science achievement of classes,

sections, or schools for purposes of comparison as in "1."

3. Measurement of general science achievement for purposes of surveys, teacher rating, or evaluation of methods of instruction.

4. Classification of pupils into homogeneous teaching sections on the basis of amount of general science subject matter already at their command.

5. Measurement from time to time of pupil or class progress in general science. For purposes of repeated measurement three forms of these scales have been constructed.

The scale is accompanied by a Manual of Directions which includes a key for the teacher. The time required for administering the scale is about twenty minutes although there is no set time limit. The computation of scores is very easy. To date the scale has been administered to approximately 40,000 pupils.

PREHISTORIC OYSTERS.

On the banks of the lower Potomac River at Wailes Bluff, near Cornfield Harbor, Md., may be seen a thick bed of oyster shells, now high and dry above tide level and covered by several feet of earth. How did they get there? Is it a kitchen midden of the long ago, left by the Indians or their predecessors? Geologists say no; the bed is vastly older than that, and the oysters lived and died where they are now and owe their present high position to changes in water level and not to human agency.

This ancient oyster bed and adjacent deposits that include a more varied assortment of shells are pictured by W. C. Mansfield in a short report entitled "Notes on Pleistocene Faunas from Maryland and Virginia and Pliocene and Pleistocene Faunas from North Carolina," just published by the Department of the Interior as Professional Paper 150-F of the Geological Survey. Although the oysters that inhabited these shells lived during the final stages of the "Ice Age," the temperature of the sea must have been about the same then as to-day, or perhaps a little warmer, for Mr. Mansfield finds that a kind of clam that now flourishes in Mobile Bay then lived near the mouth of the Potomac River.

In the course of his field studies Mr. Mansfield observed cypress stumps 6 to 8 feet in diameter buried beneath 22 feet of sea shells, sand, and clay, on the Neuse River below New Bern, N. C. He infers that the salt water of the ocean invaded a cypress swamp at this point, killed and truncated the trees, and deposited sand, sea shells, and mud upon them. This was in the later part of what geologists call the Pleistocene epoch, which began perhaps 1,000,000 years or more ago. The stumps may be as much as 100,000 years old. Later the sea withdrew, and the marine deposits were gradully cut through by the river until the old stumps thus far well preserved by the exclusion of the air, again became visible.—*Department of the Interior.*

FORMULAS FOR PARTIAL FRACTIONS.

BY RAYMOND GARVER,
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Whenever in Mathematics it is necessary to solve a considerable number of similar problems it is worth while to try to obtain a formula. That is, we solve the problem in its most general form, and the general solution will apply to particular cases when we make the necessary substitutions. Thus in solving quadratics, unless we can solve at once by factoring, we use the well-known formula instead of completing the square in each case. In solving a system of linear equations, it is usually convenient to use determinants; again we are employing a formula.

I wish in this article to apply the same principle to partial fractions, a topic of some importance in any course in college algebra or the calculus. Ordinarily each problem in the reduction of a rational function to the sum of partial fractions is treated individually; it requires the setting up and solving of a system of linear equations. But it seems well worth while to derive formulas to cover at least the more important cases. Some of the results which I state are not new, but they do not seem to appear in most of the elementary texts in spite of the fact that they are very convenient to use.

The reduction of a rational function of x, say $N(x)/D(x)$, where the degree of $N(x)$ is less than that of $D(x)$, to the sum of partial fractions, depends on the nature of the real linear or quadratic factors of $D(x)$. Hence any treatment of the problem must involve a classification on that basis. I shall consider the cases which seem to occur most frequently, and also indicate modifications necessary to treat certain other cases.

Case I. The factors of $D(x)$ are all linear and distinct. In this case the given rational function is of the form $N(x)/(x-a_1)(x-a_2)\ .\ .\ .\ (x-a_n)$, where $N(x)$ is a polynomial of degree not greater than $n-1$. This can be reduced to a sum $A_1/(x-a_1)+A_2/(x-a_2)\ +\ .\ .\ .\ .\ .\ +A_n/(x-a_n)$, where the A_i are to be determined. In the usual presentation, this determination requires the setting up and solving of a sytem of n equations in these A_i.

A much shorter method, however, is to use a formula which may be found, among other places, in Osgood's Advanced Calculus, page 11, and in Byerly's Integral Calculus, page 43. I shall not repeat the proof, as it may be found in either of these

references. It is elementary in nature; in fact the reader will be able to set it up for himself with no great difficulty. We may state the result as follows:

If $D(x)$ has the factor $(x-a)$, and if we write $D(x) = (x-a)\psi(x)$, then the numerator A of the partial fraction $A/(x-a)$ of $N(x)/D(x)$ is given by the formula $A = N(a)/\psi(a)$.

This result solves Case I completely, and so simply that an illustration is scarcely necessary. Further, it gives all partial fractions corresponding to linear factors of $D(x)$ which appear only to the first degree, no matter what other factors $D(x)$ may have. For example, consider

$$\frac{3x^2+8x+5}{(x-1)(x^2+3x+4)},$$

which can be reduced to the form $A/(x-1)+(Bx+C)(x^2+3x+4)$. By the above result we have at once $A = 2$. In this case the reduction can be completed by simply subtracting $2/(x-1)$ from the given rational function. We find $B = 1$, $C = 3$. It is well to point out that the subtraction could of course be carried out no matter what number we put in place of A, but the result will simplify properly only when the choice is correctly made.

Case II. $D(x)$ *is of the form* $(x-a)^n$. In this case the given rational function is of the form $N(x)/(x-a)^n$, where again $N(x)$ is a polynomial of degree not greater than $n-1$, and it can be reduced to a sum $A_1/(x-a)^n+A_2/(x-a)^{n-1}+ \ldots\ldots +A_n/(x-a)$. Byerly derives formulas for the A_i as follows:

$$\begin{aligned}
A_1 &= N(a),\\
A_2 &= N'(a),\\
A_3 &= N''(a)/2!,\\
&\ \ \vdots\\
A_n &= N^{n-1}(a)/(n-1)!,
\end{aligned}$$

where the primes indicate derivatives. The appearance of the derivatives would make these formulas unsuitable for a College Algebra course, but the proper formulas can be obtained easily by algebraic methods for any particular value of n, say 3 or 4. Simply substitute in place of $N(x)$ a general polynomial of degree $n-1$, and determine the A_i as you would in any particular pro-

blem. That is, the method is the same as that used in the next section.

If $D(x)$ should consist of a product of linear factors, some appearing to the first power, and one to higher power, the reduction may be carried out by first using the method of Case I, then subtracting as in the numerical example above, and finally applying the method of Case II.

Case III. $D(x)$ is the product of two quadratic factors, neither of which has real linear factors. A rational function of this type can be expressed in the form

$$\frac{ax^3+bx^2+cx+d}{(x^2+p_1x+q_1)(x^2+p_2x+q_2)} \quad (p_i^2-4q_i<0),$$

and can be reduced to a sum

$$\frac{Ax+B}{(x^2+p_1x+q_1)}+\frac{Cx+D}{(x^2+p_2x+q_2)}.$$

To determine A, B, C and D, we equate these two expressions, clear of fractions, and equate coefficients of corresponding powers of x. We obtain four equations:

$$\begin{aligned} A+C &= a \\ p_2A+B+p_1C+D &= b \\ q_2A+p_2B+q_1C+p_1D &= c \\ q_2B+q_1D &= d. \end{aligned}$$

Solving for A and B by determinants gives

$$A=\frac{d(p_1-p_2)+(aq_1-c)(q_1-q_2)+(ap_1-b)(p_1q_2-p_2q_1)}{(q_1-q_2)^2+(p_1-p_2)(p_1q_2-p_2q_1)}$$

$$B=\frac{(dp_1-cq_1)(p_1-p_2)+(bq_1-d)(q_1-q_2)+aq_1(p_1q_2-p_2q_1)}{(q_1-q_2)^2+(p_1-p_2)(p_1q_2-p_2q_1)}.^*$$

Substitution in these formulas is easier than at first appears, since many of the terms are repetitions. We may then find C and D almost immediately from the first and fourth of the above system. Use of these formulas for determining A, B, C and D will shorten the work except in a few cases where the four equa-

*I have obtained these two formulas by a different process, in The American Mathematical Monthly, Vol. 34 (1927), pp. 319-20.

tions to be solved happen to be of a particularly simple nature. Again there seems to be no need for an illustration; the formulas are self-explanatory.

It would be possible to obtain formulas for the case where $D(x)$ was the product of three (or even more) quadratic factors, but the work would of course be long. And problems of this kind do not arise often enough to require formulas.

Case IV. $D(x)$ is the square of a quadratic expression in x, which does not have real linear factors. We are thus considering rational functions of the form

$$\frac{ax^3+bx^2+cx+d}{(x^2+px+q)^2}, \quad (p^2-4q<0),$$

which are to be reduced to a sum

$$\frac{Ax+B}{(x^2+px+q)^2}+\frac{Cx+D}{(x^2+px+q)}.$$

The formulas for this case can be conveniently written as follows:

$$\begin{aligned} C &= a, \\ D &= b-Cp, \\ B &= d-Dq, \\ A &= c-Cq-Dp. \end{aligned}$$

Thus C, D, B and A are determined sequentially. They could all be easily expressed in terms of a, b, c, d, p and q, if that seemed desirable, by simple substitutions.

In conclusion, I shall simply state again that similar formulas could be obtained, if necessary, for a number of other cases.* Thus to obtain formulas for the case $D(x) = (x-a)^2(x^2+px+q)$, the work would be very much like that in Case IV.

PUBLIC-SCHOOL EXPENDITURES DOUBLED IN SIX YEARS.

Expenditures for public schools throughout the country have almost doubled since 1920, as shown by statistics of State school systems, published as United States Bureau of Education Bulletin, 1927, No. 39. Total expenditures during the school year 1925-26 amounted to $2,026,308,190. This included cost of instruction, outlay for new buildings, sites, equipment, and administration. It represents an increase over 1924-25 of $80,211,278. In 1913 the cost of public schools per capita of average daily attendance was $38.31; in 1918 it had increased to $49.12; in 1920 to $64.16; in 1922 to $85.76; and in 1926 to $102.05.—*Frank M. Phillips in School Life.*

ISAAC NEWTON'S EXPERIMENTS ON LIGHT.

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In the Ante-Chapel of Trinity College, Cambridge, is Roubiliac's marble statue of Newton holding in his hands a prism, which was the inspiration of Wordsworth's rhetorical apostrophe, in *The Prelude* III,

> "... Newton with his prism and silent face
> The marble index of a mind for ever
> Voyaging through strange seas of thought alone."

The reference to the prism suggests the great researches of Newton on light.

Immediately after taking his degree at Cambridge and having gone to the country to escape the plague, Newton purchased a prism with which to study light phenomena. The problem of colors persistently presented itself to him as one which might lead to improvements in the making of telescopes. The refracting telescope which had been invented by Dutch artists was little more than half a century old. Galileo had been the first in Italy to manufacture the instrument and the first of all men to use it as an instrument in scientific research. But it was at that time a very defective instrument affording only blurred and distorted images. Galileo's blindness is supposed to have been hastened by his persistent use of his telescope. How to improve it was the question of the day. As we now know, no real remedy was then possible, because the phenomena of light were not understood. The poor performance of the telescope was due to two principal causes, but only one was at that time recognized. It was known that a lens, even though its surfaces were perfectly spherical, would not bring to a focus the rays of light passing through it from some luminous point. This deviation from the expected or wished for behavior which took place even with homogeneous light, such as blue or red light, was called an "aberration," or more specifically a "spherical aberration." It prevented the formation of sharp images of objects, because the rays from a point of the object did not all converge accurately to one point in the image. It was early believed that this defect could be remedied by polishing the lenses in such a way as to bring about a slight departure from the spherical form of the kind that would make all rays passing through the lens to bend or refract to a point. Accordingly we find the French-

man René Descartes, when a young man, experimenting to ascertain the exact shape for the surfaces of perfect lenses. He devised certain forms called "Cartesian ovals," but in experimenting he did not succeed in actually removing all the imperfections of images.

Descartes' failure cannot be attributed wholly to insufficient skill in experimentation. This failure was due in the main to a cause not then known to exist. There was a second misbehavior of the rays of white light, a second "aberration." The old time telescope showed objects seen through it as enveloped in a fringe of color. Color effects in lunar haloes and in the rainbow had engaged the attention of Newton as an undergraduate. At that time the formation of the color of the sunset, or in glass pitchers filled with water, or in glass prisms, was not understood. White was considered a "color," just as the "red" or the "blue" are colors. Many people doubtless had no longing for a scientific explanation; they were satisfied simply with the observation of the esthetic effects, and agreed with the writer of the lines,

> "Triumphal arch that fillst the sky
> When storms prepare to part
> I ask not proud philosophy
> To tell me what thou art."

To Newton the phenomena of color made an intellectual appeal. Is it possible to improve the telescope, and to get rid of the color fringes blurring the images? It would seem that for several years Newton meditated and experimented on this problem. In 1669, his great teacher, Isaac Barrow, brought out his lectures on Opticks. Newton assisted in seeing this book through the press. Barrow had notions on color which are now considered quite absurd; red he considered to be strongly condensed light, and violet was strongly rarefied light. Newton did not suggest any changes, which would indicate that as yet he himself was not quite sure of his own explanation. Before him, refraction due to prisms was supposed actually to produce color, instead of merely to separate what already existed.

Visitors to Trinity College, Cambridge, are reminded that Newton performed optical experiments at his room in the College quadrangle. Through a small hole in a shutter a ray of sun light was admitted into the darkened room and passed through a prism. On a white wall opposite was seen, not a spot of white light, but a riot of colors—colors ranging from the red through

orange, yellow, green, blue, indigo, to the violet. Moreover, these colors did not form a round colored spot on the wall, but a long strip of light. In Newton's own words: "Comparing the length of this coloured spectrum with its width, I found it about five times greater—a disproportion so extravagant, that it excited me to a more than ordinary curiosity of examining from whence it might proceed." He varied his experiments considerably. What became of the white light which entered the room through the hole in the shutter? In place of it appeared the spectral colors. But if these colored rays are brought together again by a second prism the same as the first but placed in such a way that the refractions thus produced opposed each other, the image thus obtained on the screen was circular and white, at least in its central portions. In the first part of the experiment white light was broken upinto spectral colors; in the second these colors were combined and reformed into white light. Thus analysis was followed by synthesis. Newton expressed his conclusions as follows: "And so the true cause of the length of that image was detected to be no other than that light is not similar or homogeneal, but consists of difform rays, some of which are more refrangible than others." He had made the capital discovery that white light when refracted by a prism is broken up into its component primary rays, violet rays being deflected more widely than others, each ray having its own index of refraction. This separation of colors is called "dispersion."

Newton perceived what scientists before him had overlooked, that the phenomenon of dispersion was to blame for the main deficiencies of the refracting telescope. Spherical aberration which Descartes had tried so hard to remove, was not the only source of trouble. Color played a part. Newton discovered that "chromatic aberration" was a second and more serious mischief maker. In his own words: "The confused vision of objects seen through refracting bodies by heterogeneal light arises from the different refrangibility of several sorts of rays." It could not be remedied merely by changing the shape of the telescope lenses. Was there some other remedy?

Newton communicated his discovery of dispersion to the Royal Society of London which appreciated its importance and published it in the *Philosophical Transactions* for 1672. So novel was it to the science of that day that several critics arose—Linus, Lucas, Pardies, Hooke and Huygens. Newton was over sensitive to criticism and on December 9, 1675 wrote to Leibniz: "I was

so persecuted with discussions arising from the publication of my theory of light, that I blamed my own imprudence for parting with so substantial a blessing as my quiet, to run after a shadow." And never after this, during the fifty-two remaining years of his life, were any of his books or researches published through his own initiative; in every case publication occurred only through the persistent urge of his friends, or after his death.

Some of the criticisms related to Newton's theory of light, and will be considered later. The criticism of Lucas of Liege related to the accuracy of the experimentation and deserved more careful attention than Newton actually gave it. Lucas repeated Newton's experiment with the prism and concluded that the length of the spectrum was not five times its width, as claimed by Newton, but only three and one half times its width. Here was a wide divergence in a simple direct comparison of the length and width of the spectrum—one of the easiest measurements conceivable. How could it happen that two able experimenters should differ so widely? This question did not receive adequate study on the part of Newton. In consequence, he missed an important discovery which delayed the fundamental improvement of the refracting telescope for over three-quarters of a century. Newton was always interested in chemistry, yet it did not occur to him that, probably, the kind of glass of which the prism was made might play a rôle in his experiments. Newton felt that his measurement of the length and width of his spectra had been made repeatedly and that he could not be mistaken to the extent claimed by Lucas. He did not take steps to procure a prism made of different glass. However, the question of the material of which the prism was composed, did receive some attention; he performed one experiment, but, as it happened, by a strange perversity of fate, he missed the important discovery. In a prismatic vessel filled with water, probably impregnated with sugar of lead, he placed a glass prism and examined the rays passing through. Would this prism composed of these two different substances—water and glass—modify or remove dispersion? From his tests he thought he could conclude that refraction must always be accompanied by dispersion. It chanced that his glass prism and water had about equal dispersive powers. Other liquids would have given different results. But here Newton did not exercise his usual caution. From very limited experimental evidence he drew a broad inference, to which he adhered with marvellous tenacity, but

which was erroneous. Thus he missed the invention of the achromatic lens, which did not display color effects, and which made possible the modern refracting telescope with its wonderful clearness and sharpness of vision.

The Reflecting Telescope.

While Newton failed to reach a goal in relation to the refracting telescope, he made a brilliant touchdown with regard to the reflecting telescope. He is justly regarded as one of the inventors of the reflecting telescope and the very first actually to construct such an instrument. Several years before he published his experiments on colors, and despairing of correcting the chromatic aberration in the refracting telescope, he turned his attention to the reflecting telescope. James Gregory in Scotland and some others had suggested the idea which was fairly obvious, but they had failed to construct a working instrument or to find opticians who could carry their plans into successful execution. Newton modified the Gregorian design in several important respects. In 1668, thinking it "best to proceed by degrees," he first "made a small perspective to try whether his conjecture would hold good or not." The telescope was six inches long, its aperture was a little more than an inch in diameter, the eye-glass was a plano-convex-lens magnifying linear dimension about forty times. It was a mere toy. Nevertheless its performance, he thought, was more than what a six foot refractor could do with distinctness. With it he could see the four satellites of Jupiter. Newton felt encouraged, but owing to interruptions, he could not enter upon the construction of a new reflector until 1671, when he made a somewhat larger instrument. The rays reflected from the mirror were received upon a small metallic speculum inclined 45° to the axis of the tube which reflected the light into the eye-glass on the side of the tube. The difference between a reflector and a refractor is that in the former the light is brought to a point by reflection from a mirror, and not by refraction by a lens. Reflecton does not separate white light into its colors as does refraction through a prism or an ordinary lens. But even in reflection, "spherical aberration" prevails, but that defect can be remedied satisfactorily by discarding spherical reflectors and adopting parabolic reflectors. When it comes to the eye-piece the reflector and refractor are on the same footing; here both are dependent upon lenses. No telescope is possible having no lenses and only mirrors.

At the request of the Royal Society of London, Newton sent his second telescope to the Society, near the end of the year 1671. The instrument was shown to the King, and a description was published in the *Philosophical Transactions*. This telescope has been carefully preserved in the Library of the Royal Society to the present day, with the inscription, "The first reflecting telescope invented by Sir Isaac Newton and made with his own hands." It is a singular fact that not till half a century later was a reflecting instrument constructed which became a powerful aid to astronomical research. It was in 1781 that William Herschel discovered the planet Uranus, with a reflector made by his own hand. Since the invention, in 1758, of the achromatic lens, the refracting telescope regained its lost prestige. From that time to the present the two types of telescopes have been competing in friendly rivalry.

Newton's Speculations on the Nature of Light.

Just as Galileo was brought up on Aristotelian philosophy and later rebelled against it, so Newton as a student was introduced to Cartesian philosophy and later brought about its overthrow. Newton was in many ways intellectually indebted to Descartes. Especially is this true in the field of geometry. It was also from Descartes that he obtained the idea of explaining the phenomena of the universe on mechanical and not on animistic principles. But when it came to the details of the mechanism, Newton departed widely from Descartes. This was the case in celestial mechanics; we shall see that it was true also of light. According to Descartes the carrier of light to us from the sun or from the stars was transparent matter which filled interplanetary space; this transparent matter was composed of globules whose sizes were intermediate between the vortex matter composing the sun and the opaque, ponderous matter constituting the earth. These globules are constantly straining away from the sun or other center around which they turn, owing to the centrifugal force of the vortices, so that the globules are pressed in contact with each other. It is the transmission of this pressure which constitutes light. Colors depend upon the speed of rotation of these globules. Vision is due to pressure which we perceive in the same manner as a blind man perceives objects by the pressure these objects exert against his stick. The theory was in close entanglement with the Cartesian vortices; and it passed away when the vortices came to be aban-

doned by scientists. In place of the Cartesian globules, Hooke in 1665 and Huygens in 1678 postulated the existence of a very subtle luminiferous ether; each advanced a wave-theory of light which labored under many imperfections and serious difficulties.

When Newton was carrying on his experiments on the dispersion of solar light and spectrum colors, he proposed to himself several hypotheses, only to find that each was disproved by the facts. Like Descartes, he explained rays of light as due to globular bodies. Newton's globules did not simply "press" against others as in the Cartesian theory, but like bullets they flew through space with great velocity. He tried to explain the bending of the rays in passing through a prism by a phenomenon known in his day to tennis players, and in our day familiar to every base ball enthusiast,—the phenomenon of "curved pitching." Newton says that he "had often seen a tennis ball struck with an oblique racket, describe such a curve line. . . . For that reason, if the rays of light should be globular bodies, and by their oblique passage out of one medium into another, acquire a circulating motion, they ought to feel the greater resistance from the ambient ether, on that side, where the motions conspire and thence be continually bowed by the ether. But notwithstanding this plausible ground of suspicion, when I came to examine it, I could observe no such curvity in them." This statement affords a beautiful illustration of the use of the scientific imagination, held in check by the results of experiment. The imagination associated the subtle phenomena of light with the familiar motion of a tennis ball. The verdict of experiment was against the reality of this analogy.

Newton's papers on the spectrum and color, published in the *Philosophical Transactions* in the interval 1672 to 1676 indicate that Newton had given careful consideration to two rival theories of light, one being the wave theory advanced by Robert Hooke and later by Christian Huygens, the other being his own "corpuscular theory," also called the "emission theory." According to the latter, light consisted of very minute particles of matter traversing space with very great velocity. Newton saw full well the advantages of each of the theories and their disadvantages. He saw plainly that the undulatory theory afforded an easy explanation of the colors of thin plates and of the colors of a layer of oil spreading on the surface of water and of soap bubbles. The wave theory disposed of these important phenomena more easily than did his own theory. Why not accept it? Newton's

hesitation to do so was due to his inability to explain, on the wave theory, the fact that light does not travel around a corner as does sound. That sound is due to wave motion was generally accepted. If light is wave motion how is it that two persons stationed on different sides of a house can hear each other, even though in broad daylight they cannot see each other? If light is wave motion, argued Newton, light should behave as does sound. "To me," said Newton, "the fundamental supposition itself seems impossible, namely, that the waves or vibrations of any fluid can, like the rays of light, be propagated in straight lines, without the continual and very extravagant spreading and bending every way into the quiescent medium." The emission theory, on the other hand, offered an easy explanation. A luminous point emits streams of minute particles moving in straight lines, which cause vision by their impact on the retina. Refraction of light was explained by assuming that the flying particle begins to be attracted towards the refracting surface when it comes very near so that the component of its velocity along the normal to the surface is increased. Thus the bending of the ray was explained. As a consequence, the velocity of the particle is greater through the denser medium. A difficult point to explain on the emission theory was the fact that on the surface of a transparent medium like glass, part of the light is refracted and part of it is reflected. How can an impinging particle at one time be refused admittance and be thrown back, and at another time be given free passage into the interior? To account for this Newton advanced a strange explanation, the "theory of fits" of easy reflection and easy transmission, communicated to the flying particle by the all pervading ether. The procession of flying particles sets the ether near the surface of the glass into agitation resulting in successive compressions and rarefactions of the ether. A flying particle reaching the surface at a moment of compression of the ether is thrown back; if the particle arrives at a moment of rarefaction, the path is less obstructed and it passes through. This is Newton's explanation of how a surface of glass or water partly reflects and partly refracts rays of light composed of flying particles.

It is worthy of observation that Newton's emission theory postulates the existence, not only of the flying particles constituting light, but also of an ether. It postulates all the mechanism needed for the wave theory, and more. From the standpoint of economy of assumption, the wave theory has the advantage.

On this point uncritical students of the history of science have labored under a misapprehension. They took for granted that Newton's abandonment of the wave theory carried with it the discarding the luminiferous ether. Such a statement is inaccurate in two respects; Newton did not discard the ether, nor did he altogether abandon the wave theory. He fully recognized the power of the wave theory in explaining the color effects of thin plates and soap bubbles, but he failed to see how this theory could explain the rectilinear propagation of light. It remained for physicists of the nineteenth century to show, by careful mathematical analysis, that the wave theory is capable of doing this, that the diminished ability of light, as compared with sound, to go around a corner, can be satisfactorily explained by the fact that the wave length of light is so very much shorter than that of sound. The nineteenth century was a flowering time of the wave theory; the emission theory was laid aside as an interesting historical relic. But the history of science reveals strange reverses of judgment. Ideas disowned by one generation may be cherished dearly by the next. The discarded light corpuscles of Newton have reappeared in modern garb in the quantum pellets of Max Planck and in the light quanta of Einstein. There is a difference between Newton and Planck in this, that Newton assumed the corpuscle of red light to be heavier than the violet corpuscle, while with Planck the relation is reversed. Newton hesitated between the wave-theory and the emission theory. Modern physics has been in the same quandry. The tendency of the hour is not to discard the one nor the other, but to seek a coordinating principle. Such an one is the new wave mechanics suggested by Louis de Broglie and Schrödinger which endeavors to fuse the wave theory and the corpuscular theory into one more general and harmonizing system. It is interesting to find that Newton's theory of "fits" of easy reflection and easy refraction involves a mechanism similar to that of de Broglie. Newton considered the ether waves as traveling faster than the light corpuscle. De Broglie considers a group of waves enveloping a mass-particle and traveling with it as a sort of body guard, but the individual waves travel faster than the group and the particle. These are interesting coincidences.

THE AMERICAN PHYSICAL SOCIETY

Pomona Meeting, June 15, 1928

THE MINUS SIGN IN VERTICAL SUBTRACTION IN ARITHMETIC.

By G. W. Myers,
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The systematic employment in arithmetic and in arithmetical test materials of the minus sign to mean "subtract", before the subtrahend of a subtraction example vertically arranged, thus—

$$\begin{array}{r} 364 \\ -182 \\ \hline \end{array}$$

is vigorously objected to by many teachers of first-year algebra. The objection narrows down to an alleged difficulty that beginners in algebra experience in accustoming themselves to regarding such an example as the one just cited as an *addition* example with a negative addend, after long habituation to regarding it as a *subtraction* example in the arithmetic. In algebra of course such an example is always regarded as an addition example. Only a moment's reflection is however needed to convince one that such an example can be regarded as an addition example only under a more extended conception of addition than the conception which functions in arithmetic.

The contention of the objector seems to be that the resistance to the required change of thought arises mainly out of the strong habituation that goes on in the arithmetic through the systematic setting of mechanical subtraction practice-exercises before the pupils in the aforesaid form. This habituation establishes the mental set of attaching the meaning "subtract" to the minus sign in this position before the subtrahend, whereas in algebra it must mean "negative" in this position. The remedy urged is to discontinue the use of the "subtract" connotation in subtraction examples in arithmetic.

It is the purpose of this paper to set forth briefly the reasons that exist in defense of the arithmetical practice. The writer would say moreover, that he regards himself more a teacher of algebra than of arithmetic, having been intimately concerned with the teaching of algebra for a much longer time than with the teaching of arithmetic. Perhaps his acquired sympathies are then fully as strong for the algebra as for the arithmetic teacher.

1. Almost all arithmetic teachers and practically all arithmetic texts have long been following the practice in question;

grade children like it, and teachers find it really helpful in arithmetic. This is at least a strong pragmatic reason for continuing the practice. That it works well and easily, that it facilitates work for both pupil and teacher and is enjoyed by all concerned, are about the strongest known reasons for continuing to employ a teaching device or technique, even though subsequently on a higher level of maturity some minor difficulties may arise.

2. The requirement of learning a symbol through its functioning and the equable distribution of emphasis upon coördinate symbols demand the retention of the practice in question. It is customary in arithmetic to employ all the symbols +, −, x, and ÷, before the number which is the operator, partly to secure thorough mastery of the symbols through their uses and partly to assist pupils to develop a general skill in interpreting operational symbols whereby the learner may acquire both readiness and versatility of control over the symbols. Also alertness and attention to meanings and directions are greatly fostered.

To accede to the objections to this usage for the minus sign would either entail a complete abandonment of this use of all four of the symbols, or make a special exception of the minus sign, leaving it quite unpracticed. The first alternative violates the wholesome law of learning, "Teach a thing when it can be made to function, and thereafter can be kept in function." The second alternative would require the unbalancing of the practice emphasis on the four operations to the great disadvantage of subtraction.

3. After subtraction has been absorbed into the enlarged concept of addition in algebra, so that any subtraction example may be regarded, after suitable modifications, as an addition example and after division has likewise gone over into an enlarged multiplication, a rather complete recasting of old arithmetical points of view and forms of thought, becomes a necessary and an intrinsic duty of algebra. This bringing the extended and generalized view of number and its new calculus into accord with the newly defined operations and techniques is in fact the begetting of algebra. Algebra is only generalized and extended arithmetic, and generalizing and extending activities are a bit severe for the young algebraic novices of our day, but for those who go on to algebra such difficulties as are thus encountered are intrinsic and cannot be evaded. This would seem to mean that arithmetical elements of fundamental import to algebra must be marshalled into such order as the algebra teacher deems

necessary as a basis for the superstructure he intends putting upon it by the algebra teacher himself.

4. No one objects to the ample use in arithmetic of the minus sign in the operational sense in horizontal arrangements, such as $364 - 182$. It would seem to be both correct and clever teaching to lead the pupil to see that the form

$$\begin{array}{r} 364 \\ -182 \\ \hline \end{array}$$

means precisely the same as the horizontal form $364 - 182$, but that the vertical arrangement is merely in more convenient form for managing long and more difficult written examples, for it tells both what to do and fixes an order for the numbers that obviates most of the copying, otherwise necessary. It seems artificial and arbitrary to say to the arithmetic teacher: "we will approve your using the minus sign for 'subtract' if you place the numbers in horizontal array, but we forbid this use of the minus sign if you order the numbers vertically." There is indeed real advantage in habituating the pupil to seeing in the vertical as well as in the horizontal arrangement merely the short direction: "364, take away 182," or "364, subtract 182." This is still true even though in algebra the underlying concept is: "what added to 182 will give 364?"

5. In arranging mixed drills on a printed page where examples in all four of the fundamental processes are intermingled, as they are in drills built primarily for holding already acquired skills, it is both a convenience and a saving of space, with gain both in clearness and page appearance, to label the "operator-number" in each process with its appropriate $+$, $-$, x or $\div$. This practice also furnishes an increased and variant use of the symbols for the basic operations beyond what would be otherwise available, especially for the minus sign, and this is no inconsiderable gain to the pupil in the matter of symbol-control. The pupil needs facile habituation to a variety of ways of recognizing meanings and to a variety of experiences in "husking" out the essential process from very diverse situations calling for it.

6. There are two principles that are dear to a mathematician's heart, to be persistently recognized in the development of the separate disciplines of mathematical science, principles that are older and more fully seasoned than anything in modern peda-

gogy, for they have been consciously employed by good writers of mathematical texts since the time of Vieta (1540-1603), who first gave them explicit statement and employed them extensively. The authorship of them indeed constitutes a good part of Vieta's title to the cognomen, "The Father of Modern Algebra." These principles are just as applicable in arithmetic as elsewhere. The first of them may be termed the principle of "Permanence and Extension" and the second, the principle of "Ample and Varied Partial Practice." These principles enjoin the practice in question with reference to the use of the minus sign on the basis of the law of analogy. For example, witness the following analogies:

A. Speaking from the viewpoint of mathematical interests arithmetic is only a preparatory and preliminary stage to algebra, passing over into algebra with full validity. Everything in rightly learned arithmetic is first accredited in full and then merely extended, enlarged and generalized to yield algebra. Arithmetic and algebra are then only extended, enlarged and generalized to yield analytics, and so on through the several separate disciplines or branches of mathematics. The antecedent branches or stages of advance are only partial and preparatory stages to the next subsequent stage to a greater extent in mathematics than is the case in any other field of exact science.

The second of the two principles cited demands ample and varied habituation of each preceding stage even though it be a partial stage, as the best known propaedeutic to the succeeding stage. Moreover the habituations in each stage are to be carried out entirely within the field of number and process that is appropriate to that stage. This is the meaning of the application of the principles to the several branches in their entirety. This of course presupposes a sound arithmetic, devoid of such spurious so-called principles as "the product must be of the same name as the multiplicand and the multiplier must always be abstract," or "multiplication always increases and division diminishes the number it is performed upon."

B. Furthermore the constituent elements within each of the succeeding disciplines demand like treatment under these basic laws of the evolution of quantitative thought and technique, towit:

(a) The number concept itself must grow through the partial stages of integer, fraction, mixed number, rational and irrational number, negative number to the final stage of complex and

hypercomplex number. Each partial stage treated under the two basic laws, demands that the meaning of number in each subsequent stage shall include within itself the meaning it had in the antecedent stage, and shall then merely enlarge and extend it.

Then the second law requires thorough habituation within the limited scope of its applicability, neither mitigating nor slurring the habituation because forsooth in the subsequent stage something else is to be habituated. Each partial concept is to be thoroughly exploited within its own limited range.

(b) The exponent concept is another example of an ever-enlarging notion, in connotation passing through the stages of positive integer, positive fraction, negative integer or fraction, rational or irrational number, negative number, imaginary and complex number. The same two basic laws are operative here, demanding acceptance of the old connotation at each new stage, and then thorough exploitation within the relatively narrow, but ever-growing limits of each stage.

(c) The operation of multiplication also has a growing connotation through the domains of integers, fractions, mixed numbers, negatives, rationals, irrationals, imaginaries to complex numbers, changing its connotation at each advancing stage by the inclusion of the old connotation, and then extending and enriching it. The change of function of the altered concept is never that of discarding the preceding connotation and adopting a new and essentially different one.

It is this evolutionary character of mathematical science that constitutes it a "cumulative" science, accepting and accrediting from age to age as well as from stage to stage, the sound findings of each preceding era or stage and then merely extending, enlarging and generalizing the old findings. Physics, chemistry and the other scientific disciplines may from time to time revise and radically change the nature of the entire foundation on which they build, not so mathematics. The findings and methods of the ancient Greeks are as valid today as they were 2400 years ago.

(d) Like all the rest of the growing mathematical concepts the concept of minus $(-)$ must pass through its transitional stages of subtract, deficiency, shortage, below zero, oppositeness, quality, negativeness, to the final full-blown meaning of "subtract-negative." This composite verb-adjectival connotation of algebra entails the readjustment and readaptation of certain

processes and principles involved in their use, but the foregoing basic laws operate here also. The important point is that the second law enjoins upon the teacher to demand thoroughgoing habituation of the provisional meaning of each stage as the best preparation for the next stage. The competent and conscientious teacher must see that this habituation is carried out by the learner. The practice of using the minus sign in the operational sense before the subtrahend of written subtraction examples should then be thoroughly habituated and not at all abandoned.

Furthermore, the principle of "Permanence and Extension" would seem to imply what experience in the classroom bears out as sound pedagogic doctrine, viz.: "The duty of the grade teacher of arithmetic is so to teach arithmetic that it will function socially and in the affairs of daily life, but it is the algebra teacher's duty so to select from and to reshape, if necessary, this social arithmetic as to make it a suitable scientific basis for an algebra. The algebra teacher it is who is responsible for putting down the right foundation for algebra, quite as fully as he is responsible for putting on the foundation the proper superstructure."

It is then the high school teacher's job to extend the subtract-concept for minus through the deficiency, shortage, direction, quality and negative as intermediate stages to the final stage in which the minus has the ambiguous "verb-adjective" connotation and to follow out and clear up such confusion as inheres in this ambiguous implication of the minus sign in algebra.

The remedy, if any is needed, for the allegedly strong habituation to the use of the minus sign in the subtraction, or operational sense, that the pupil brings from arithmetic to the beginning of algebra is not at all for the elementary teacher to "lay off" the practice, but rather for the high school teacher to "lay on" the extension and enrichment of it into the appropriate algebraic usage. It is the algebra teacher alone who knows what manner of development and procedure the algebraic beginner is going to be required to experience, and hence what sort of foundation for the scientific purpose in hand will be most needed. The transition from the operational meaning of minus to the composite "operation-quality" connotation, for it must be a gradual transition looking forward to the new field rather than backward to the old, is and should be in the hands of the high school teacher.

Finally, thirty-five years of experience with the teaching of algebra convinces the writer that the *alleged* confusion arising in the early algebraic work from the extension of the minus with

its verb-sense that comes from arithmetic to the adjective-sense of algebra, such as it is and it is mainly an "alleged" confusion,—is *inherent* in the situation as a mild growing pain for beginning algebra, that its seriousness is quite incommensurate with the noise that is made about it, and that relief is not to be sought in the abandonment of an elementary school practice. Some little real difficulty is experienced but it is inherent and is precisely the difficulty that is always attendant on generalizations from the arithmetical to the algebraic setting. To abandon the arithmetical practice would not help but would hinder algebraic beginnings. A main job for the algebraic learner is the acquisition of the difficult but extremely valuable skill in generalization. He will not require such skill by practicing none of it. The extension of the minus-meaning is only the natural experience of the algebraic "toddler" in learning to take the first and early steps in algebraland.

To "soft-pedal" the use of the minus in the operational sense of arithmetic is to repudiate the very genius of mathematical learning and growth. Sound educational tenets are already in entire accord with the above-cited master principles of the mathematical educationist and the other type of educational tenet will when the tenet-maker learns enough of the matter of mathematics to have the "mathematical *feel*," be brought into accord with these same norms.

IS "CORONIUM" DISGUISED ARGON?

Coronium, the mysterious substance in the sun's corona that only manifests itself in spectrum photographs made at the time of a total solar eclipse, is probably due to argon, third most abundant gas in the air. This has been found by researches carried on at the Ryerson Physical Laboratory of the University of Chicago, by Dr. Ira M. Freeman.

"Coronium" was first found in 1869 when, in the eclipse of that year, astronomers noticed a strange line of green color in the spectrum of the corona. This is the extremely rarefied outer layer of the sun that is visible only when the central disc of the sun is obscured by the moon. Ever since that time physicists have been trying to find the cause of it and a group of unknown lines that were later discovered.

Dr. Freeman has found that 18 of these lines can be identified as those of the element argon, which occupies nearly one per cent. of the atmosphere. Other observations of the sun with the aid of the spectorscope have never shown the presence of argon, but, Dr. Freeman points out, it may well be that it is present but that it is quite possible the condiitons on the sun are not just right for it to be in evidence ordinarily.—*Science News-Letter.*

A LABORATORY METHOD IN PHYSICS.

By Carl P. Utterback,
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For many years attempts have been made in this school to work out a method for presenting laboratory exercises and laboratory problems in High School Physics that would be free from some of the objections common to the usual methods employed. This study has been motivated by a desire to obtain something which may replace, in our classes, the usual manual or loose leaf systems, without sacrificing any of their good features and which must, in addition, meet the following demands:

1. It must apply directly to the apparatus in the laboratory.
2. It must be flexible.
3. It must permit of the organization of results into a short written report.
4. It must require cooperative work among pupils.
5. It must include fundamental experiments within the abilities of *all* pupils and, at the same time, provide well for individual choice, desire and indifferences.

Many methods have been tried thoroughly, modified, and combined with other methods. Close observations have been made to measure the results, the time required, the amount done by pupils of various abilities, the retaining of information, and many other factors. As a result, the method or system to be described has been developed and has been used in this school the past three years.

A typewritten sheet, called the Instruction Sheet, is provided for each exercise. On this is a statement of the problem, a list of the apparatus and material required, and a short discussion of the theory involved, if this is deemed necessary. Next follows complete directions for carrying out the problem, together with a drawing of the assembled apparatus or of some part of the apparatus. The drawing has been carefully worked out, so that it is a direct aid to the work. Cautions regarding probable sources of error and the correct handling of apparatus are stated. Correct procedure is emphasized and logical sequence is rigidly

maintained. The final paragraphs on the sheet consist of statements and questions designed to assist the pupil in forming conclusions, both specific and general, concerning the work he has done.

The instruction sheet is fastened with shellac to a light wooden frame, having a cardboard back. Then both sheet and frame are coated with shellac and later varnished. A sufficient number of copies of any one exercise is provided for a large class. The number of copies required will vary from one to six, depending on the type of the experiment, the time of the year in which it is used, and whether it is required of all pupils. Each frame is numbered by attaching a paper tag, and is filed so that it is readily accessible to all pupils. Each set of directions is, then, a separate unit.

When this system was first used, it was discovered that a large majority of high school pupils were unable to tabulate or otherwise arrange numerical data in an orderly manner. This inability was due to a lack of any previous experience in these particulars. The following method of teaching the tabulation of data has been developed and is now a part of the instruction system.

For each experiment performed during the first semester and for the more difficult ones of the second semester, there has been prepared a "Suggested Form for the Tabulation of Data." This form is drawn with India ink on a heavy white paper. It is neatly arranged and in most cases the column headings are lettered in. Each form is mounted behind a glass cover and is bound to the glass by an adhesive binding. The forms are placed on large boards, prepared for the purpose, which hang on the walls of the laboratory. Each of these boards contains twenty-five forms. Each board is so arranged that any form may be easily removed in case it is to be changed or discarded. The forms are numbered to correspond with the numbers on the instruction sheets for the same experiment.

When a class enters the laboratory, each group of two or more pupils, is assigned an experiment for the day's work. One pupil immediately obtains the proper instruction sheet and collects the necessary apparatus. While he is doing this, another one makes a rough copy of the Table of Data,

as suggested. Then both together, with the apparatus they are to use before them, they study the directions for carrying on the experiment. After this, they proceed with the exercise, taking notes as they continue. In many cases a simple drawing is made during the experiment or immediately upon completing it. The drawing is made from the apparatus in use. Next, everything is put away properly, the table cleaned and the report written. The majority of reports are written in the laboratory, although a few are written elsewhere.

Some advantages of the method will be stated. During the course of a year, it saves an immense amount of time, because the directions apply to the apparatus at hand and require no modification. This saving is noticed most at the beginning of the period, as the work starts with no delay. Also, during the period, pupils are not idle as the directions are written in such a way that changes in procedure are unnecessary.

With this method in use, pupils require much less help in carrying out an exercise. In fact, just enough help is given to prevent a failure, and that in most cases is comparatively little.

The flexibility of the entire method is one of its chief mechanical advantages. If, for any reason, an experiment is to be discarded, it is but the work of a moment to remove it from the course. If a new experiment is to be introduced, a very short time is required to write the directions and to suggest a form for the tabulation of data. This flexibility is very noticeable, also, when a change is made in apparatus.

The number of experiments that may be included is almost unlimited, although a certain minimum requirement is maintained. This, of course, includes all those exercises considered fundamental.

Pupils of higher ability accomplish much more in a semester by this method than by former methods. The very poor pupils, however, do about the same amount of work.

It is possible to have two, three, or even more experiments differing in detail but covering the same principles. This allows pupils considerable choice without detracting from the value of the semester's work.

PRESENT INADEQUACIES AND SUGGESTED REMEDIES IN THE TEACHING OF HIGH SCHOOL SCIENCE.

BY A. W. HURD,
University High School, Minneapolis, Minn.

This article represents an attempt to discover what authoritative writers on the subject believe to be inadequacies in the teaching of high school science. Those interested enough to write upon the subject after considerable experience in the field, should be able to give some valuable suggestions on desirable improvements. While the subject receiving primary attention is physics, the conclusions are probably equally valid in the case of all high school science.

It may be considered as a clearing house, or a consensus of opinion of certain writers, writing between 1900 and 1926. The longer period is divided into two shorter periods, viz., from 1900 to 1912 inc. and from 1913 to 1926 inc., in order that any shifts of emphasis might be noted.

The process is one of tabulating certain statements from these writers bearing upon the subject, and attempting to find bases for a consensus of opinion. Ninety-two statements of fifty-two authorities writing between 1900 and 1912, and one hundred thirty-two statements of fifty-eight authorities writing between 1913 and 1926 (May), constitute the sources of this analysis.

The following samples show the kinds of statements tabulated: lesson assignment from text inexcusable; lack of few accepted common aims; content too bulky; too abstract, theoretical, mathematical and specialized; subject matter should be adapted to individuals; teachers need more definite training for the job; problems are too detached from life; too much mechanics; a few well-chosen problems; change to meet modern needs; the subject needs vitalization; relate subject matter to life; better methods; pupils should not be trained for physicists; too much note-book work; too minute directions; too much authority; guide, not force or lead; motivate pupils; better methods of measuring achievement; research needed on teaching methods and materials; segregate boys and girls; too much laboratory, too little demonstration; make pupil surveys; too much college oversight; new texts are needed; library books needed in the classroom.

It is possible after careful analysis to combine the total number of statements under the categories which follow; these cate-

gories being put in the form of positive suggestions of remedy, which, in themselves, suggest the inadequacies:

1. Well defined aims and objectives.

2. Well chosen subject matter suited to the needs of the pupils.

3. Better selection and training of teachers for the particular job in hand.

4. Greater responsibility and freedom of action of pupils with motivation emphasized.

5. Methods of science used to determine future changes in the course.

In considering the number of statements which may be listed under each category, the following table will be of interest:

TABLE I.

Summary of Statements on Present Inadequacies and Suggested Remedies. (110 Authorities.) Per cents to nearest whole number.)

Category	Number Statements 1900-12	Number Statements 1913-26	Per cent Statements 1900-12	Per cent Statements 1913-26	Total Statements	% Total Statements
No. 1	4	14	4%	11%	18	8.4%
No. 2	67	77	73%	58%	144	64.3%
No. 3	18	12	20%	9%	30	13.3%
No. 4	3	13	3%	10%	16	7 %
No. 5	0	16	0%	12%	16	7 %
Totals	92	132	100%	100%	224	100 %

The point stressed by the great majority of the writers is Number 2, that the most desirable remedy is well chosen subject matter suited to the needs of the pupils. The inference is that the subject matter now presented to pupils is in many cases, to say the least, not well chosen to fit the needs of the pupil groups being taught.

If one asks the question, "why is it true that three months, or six months, or a year, or two years, after having studied science (and this applies equally well to most of our school subjects) the average pupil knows very little about the material covered in his course?" the answer is fairly obvious. Some teachers might say, it is because the material was not learned to the point of mastery. Others might say that it is because the material is not closely enough associated with the daily life experiences or the needs of the pupils; the subject matter does not tie up with life; it doesn't function, therefore, it is soon forgotten.

This is such an outstanding criticism that it will become us, as teachers of science, to investigate more fully its truth or falsity.

If it be true, how can we select subject materials which are more closely associated with life activities; how can we eliminate those materials which do not function in the lives of pupils? This is the most critical problem demanding satisfactory solution before the teaching of science can be successful in the highest degree, according to this analysis.

This category, together with Number 3, "Better training of teachers for the particular job in hand," constitutes 93% of the statements from 1900 to 1913.

The statements from 1913 to 1926, however, emphasize these to some lesser degree, but 67% of the statements in this period being grouped here. For this period, there is considerable stress on Number 5, "Methods of science should be used to determine future changes in the course"; on Number 1, "Well defined aims and objectives"; and on Number 4, "Greater responsibility and freedom of action of pupils, with motivation emphasized." The remainder of the table speaks for itself.

If this analysis be worthy of serious attention, and it should be, representing, as it does, such a large number of authorities in the field, the task of the conscientious teacher and curriculum builder is somewhat clearly defined. A common-sense, inclusive survey should be made of the field of high school instruction to discover and isolate more clearly desirable aims and objectives; adequate steps should be taken to find the important subject materials best adapted to accomplish these aims and objectives; the training of teachers to carry on the instructional work should be more definitely planned and executed; the pupils must be made to feel that, in the last analysis, they are the responsible parties to plan and carry out their own projects, which implies that they be given more opportunity for individual initiative;—all of these procedures being predicated on the assumption that careful, analytic, open-minded, common-sense methods be used in the process.

Nothing can be more un-philosophical than to be positive or dogmatical on any subject.—*David Hume, Scottish philosopher and historian.*

Every one will recognize Mr. Bryan, for example, as a pure dogmatist, but not every scientist will realize that Ernst Haeckel was an even purer one.—*Robert Andrew Millikan in the Commencement Address at the California Institute of Technology, June, 1926.*

ON THE PLACE OF SCIENCE IN EDUCATION.

A report presented to the Council of the American Association for the Advancement of Science at the Second Nashville Meeting, December, 1927, by the Special Committee on the Place of Science in Education.

PREFATORY NOTE.

The organization of the Special Committee on the Place of Science in Education was authorized and its chairman was named by the Association Council at the third Cincinnati meeting of the Association, in December, 1923. The membership was made up in the following year. It was decided to undertake a prolonged study of facts and tendencies in present science teaching in the United States, while stimulating, as much as possible, further specific investigations in this field. A plan of procedure was approved by the Committee and printed in *Science* for December 12, 1924.

Under the guidance of the Committee, and with much appreciated assistance from the United States Commissioner of Education, John J. Tigert, a "Bibliography of Science Teaching in Secondary Schools," was published by the United States Department of the Interior, Bureau of Education, as Bulletin No. 13, (1925). This publication may be secured from the Superintendent of Documents, Government Printing Office, Washington, D. C.; price, twenty-five cents.

The present report was prepared by the chairman of the Special Committee, with criticism and advice from the other members. The report was presented to the Executive Committee of the American Association and was referred to the Council at the second Nashville meeting. The Council accepted the report and authorized its publication by the Special Committee. (See paragraphs 24 and 25 of the Legislative and Executive Proceedings at Nashville, *Science* for January 27, 1928, page 90.) A brief summary by the chairman of the Special Committee appeared in the general reports of the second Nashville meeting, *Science* for January 27, 1928, page 95. At the request of the chairman, who was abroad at the time, the full report is now published under the direction of the vice-chairman.

The American Association for the Advancement of Science unites with the Special Committee in the hope that this report may be a useful contribution toward an improved appreciation of the now generally discussed question regarding the place in education that should be held by the sciences and by science in general. Reprints of the present publication may be secured from the vice-chairman, Elliot R. Downing, The University of Chicago, The School of Education, Chicago, Illinois, or from the office of the chairman.

BURTON E. LIVINGSTON,
Permanent Secretary.

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The **report** is organized under the following headings:

I. The Committee's Understanding of its Functions.

II. The Search for Enduring Knowledge and the Growth of Confidence in the Guidance of Scientific Truth.

III. Obligations Accompanying the Possession of Science Knowledge.

IV. Educational Programs and the Natural Sciences.

V. Summaries of Types of Specific Studies Relating to Educational Uses of the Natural Sciences.

VI. Those Who Teach Science.

VII. Those Who Have Developed Science.

I. **The Committee's Understanding of its Functions.** The Committee appointed to formulate a statement upon the above question has interpreted its task as relating in the main to the aspects of science which affect the lives of people in general, including the uses made of the sciences in schools and colleges. The instructional

uses of the sciences constitute but a part, though a highly important part, of their whole use.

II. **The Search for Enduring Facts and the Growth of Confidence in the Guidance of Scientific Truth** are increasingly characteristic of modern thinking. In his address before the members of the American Association for the Advancement of Science in 1925, the President of the United States said: "It is a wonderful thing to live in a time when the search for truth is the foremost interest of the race. It has taken endless ages to create in men the courage that will accept the truth simply because it is the truth." The eminent speaker doubtless was thinking in comparative terms when he thus credited this age with having left off its devotion to unsupported authority, with having given up its fear of truth wherever found, and with having developed a courage and confidence that guidance is safe only when it rests upon established truth. The speaker did not maintain that the majority of men search for truth nor that the majority yet show the courage that will gladly accept new truth.

There is a growing human habit of studying the Nature of which we are part, of observing to discover cause and effect in the occurrences about us, and of applying the laws found to our own actions. Primitive minds in earlier generations were completely controlled by whatever of their surroundings, natural or human, they chanced to encounter. It truly was a great gain when human minds began to study natural phenomena and to control themselves by the facts and principles gained through careful study. But such control is only well started and needs emphasis constantly so that it may be more rapid and more widespread. What is the common attitude, for example, toward that part of science which deals with human health? It seems that people are still careless and indifferent about personal and community health. What's the use of an improving world if we are not able to live in it? People may live longer than was formerly the case, if they really wish to do so. From an important recent publication we quote certain figures showing how expectancy has changed in three cited situations.[1]

NUMBER OF YEARS EXPECTATION OF LIFE AT BIRTH.

Geneva	16th Century	21 years
	17th Century	26 years
	18th Century	34 years
Massachusetts	1789	35 years
	1890	43 years
	1897	45 years
United States	1900	49 years
	1910	51 years
	1920	55 years
	1927	58 years

These figures are highly significant in showing in general terms how much longer people live on the average in this modern scientific

[1] Fisher, Irving. "Lengthening Human Life in Retrospect and Prospect," American Journal of Public Health, January, 1927.

age than they formerly did. Of course those who would have longer lives need to make personal use of modern science knowledge.

A more specific illustration makes still more clear the relation of health knowledge to modern legal and social institutions and shows that it is those who know and act as their knowledge dictates who have their lives lengthened. Human disease, caused by known or unknown parasites, is and will probably continue to be one of the chief objects of scientific study. In such a disease as smallpox the causal parasite is not yet known, but effective means of treatment are known. People need not die from smallpox if they will guide their actions by truth, now available for all who will use it. But note the facts as summarized from a report issued by the Association for Medical Progress.

CLASSIFICATION OF SMALLPOX CASES AND DEATHS, 1921-1926, ON BASIS OF LEGAL REQUIREMENTS IN THE VARIOUS STATES RELATING TO VACCINATION OF SCHOOL CHILDREN.

	Total Population	No. of Cases	No. of Deaths	Average Annual Rate Per 100,000 Population Case Rate	Death Rate
1. States with laws requiring vaccination: Ark., D. C., Ken., Md., Mass., N. H., New Mex., N. Y., Pa., R. I., S. C., W. Va.	36,680,000	20,973	189	9.5	.09
2. States in which compulsory vaccination is optional with local health board: Ala., Conn., Ga., Ind., Mo., N. J., N. C., Ohio, Ore., Tenn., Texas, Va., Wyo.	38,444,000	111,900	935	48.5	.41
3. States in which vaccination is compulsory only when smallpox is present: Col., Ill., Iowa, Kan., La., Mich., Miss., Mon., Neb., S. D., Ver., Wis.	26,618,000	87,623	1,275	54.9	.80
4. States in which compulsory vaccination is restricted: Ariz., Calif., Fla., Me., Minn., N. D., Utah, Wash.	12,123,000	74,271	1,171	102.0	1.60
5. Status of vaccination undetermined: Del., Idaho, Nev., Okla.					

Many detailed studies have been published, also, and might be cited to show that vaccination will protect people against smallpox. Until people really believe this truth strongly enough and in sufficient numbers to secure compelling legislation, varying percentages will continue to die. This is nature's penalty which she exacts from those who do not know, or knowing will not act, or those unfortunate members of human society who are unwittingly injured by associating with those who will not apply scientific knowledge.

When harassed by those who *argued* against vaccination Dr. William Osler, famous scientific physician then engaged in England, issued the following challenge, "I will go into the next severe epidemic with ten selected vaccinated persons and ten unvaccinated persons. I should prefer to choose the latter—three members of Parliament, three anti-vaccination doctors, if they could be found, and four anti-vaccination propagandists. And I will make the promise neither to jeer nor to gibe when they catch the disease, but to look after them as brothers, and for the four or five who are certain to die I will try to arrange the funerals with all the pomp and ceremony of an anti-vaccination demonstration." It is not recorded that anyone offered to accept Dr. Osler's challenge.

It seems impossible to have such science knowledge as that pertaining to health become most useful until it is built into one's emotions and his social relations, as well as into his thinking, consciousness, and appreciation. In an earlier day children in schools and in homes frequently were affected with a form of "itch" caused by a very small epidermal insect. In closed, unventilated and unclean school rooms and homes this insect could thrive and extend its disturbances to all with whom it came in contact. During the childhood of many persons living now, to have the "itch" was an annoying misfortune but not a social disgrace. When the facts about the parasite became known, its relation to uncleanness and carelessness was demonstrated, and the "best families" didn't have it. Soon it became a social disgrace not only to have the disease, but even to perform those active superficial manifestations which indicate an itching epidermis. Today "itch" is almost unknown and so objectionable as to make even this use as illustration seem disturbingly bold. Likewise, much other science knowledge must be carried beyond mere knowing into the field of social use, into codes of human relationships, before it is most readily effective.

It must be recalled that in the very nature of things, newly discovered truth is at first in the possession of one or a few persons. No matter how helpful the new truth might be, the majority, indeed almost all persons, will be uninformed about it, hence may be unsympathetic with its use, until they become informed in some convincing way. A voting majority in a democracy is a serious menace unless it is an educated citizenry. Probably each great scientific discovery would have been voted down if its case had been left to popular vote. We need but turn the pages of history to read of the hundreds of Gallileos, Harveys, Newtons, Huxleys and Darwins whose discoveries were voted down by the large majority. Fortunately gravitation, heart-beats, attraction of planets, and forces that control the development of living things, have not yet heard the voice of the majority.

Persons who have travelled much about the earth, report that probably the majority of the human race would still vote that the earth is not round; that some form of incantation gives at least temporary protection from disease; that supplication for rain is effective; and that taboos and mystic signs are potent in curing human ills and in contributing to the welfare of the believer and his friends. Majorities are very dangerous, if uninformed. The process of informing is slow. It is opposed by belief in what has been known, by lack of intellectual desire and vigor on the part of many, and by intellectual and social "vested interests." Slosson has said: "In actual life ignorance is allied to conservatism, and the combination is a strong one. In order to introduce a new idea into the mind of man it is generally necessary to eject an old idea. To move in new furniture one has first to move out the old."

It must be recalled, also, that only a few discover new truth and that these few must inform the many. The many must be informed in terms and by examples within their own range of experience. It is useless to hang up a light whose rays are outside the range of vision of him for whom it is put up. He may be outside the range in mere distance, or his sensitiveness to light may not fall within the scope of the light waves in use.

Then it must be further recalled that rapidly growing knowledge, increasing intellectual effort, and accumulating regulations of human conduct cause added tensions upon minds. Often these minds are unused or ill-adapted to added intellectual and social loads, and prefer to evade the somewhat unnatural strain. It is easier to vegetate than to work, and growing knowledge illy suits an increasingly quiet life. It is only when the rewards of scientific knowledge are greater than the comforts of a quiet life that dissatisfaction arouses to the necessary effort for gaining new ideals.

Science instruction both in school and out needs better organization, more effective cooperation to make even the health knowledge now available function more completely in the lives of people generally.

III. **Obligations of Science Knowledge.** There are so many statements regarding the constant application of science in everyday life, that it would be superfluous to add such a recital in this report. A brief reference only is made as a basis for the discussion of the obligations involved. The citizen uses modern science, both its subject matter and its method, at each turn of his day's work: he uses it in his problems of food selection, in his transportation, his communication and his recreation. If he is a thinking citizen, he is ambitious to profit by what he understands as scientific facts, principles and occurrences; if unthinking, he reaps the benefit of his fellows applications. An industrial manager wants his operators to possess knowledge of materials and processes which science has produced for the improvement of the quality and quantity of output, as well as for the better life, comfort and thinking of his men. A lawyer or preacher desires factual and meaningful illustrative material from the working world of science so as to make his case convincing to those who live in the modern world. The teacher must make the most far-reaching use of science of all, for he deals with those who are coming into the opportunities and obligations of the heritage of an age which

science has made unlike any of its predecessors. In industry, commerce, and the professions, progressive workers must have knowledge of science, and even more, of the methods and ideals by means of which truth is growing. There is a widespread and keen, even though by no means universal, interest in a genuine interpretation of science as it appears in the street, factory, home and recreational centers. And the philosopher now finds that the truth, the principles and the final objectives of science provide a new and more secure basis for his philosophy, a means of better organization of his thinking, as well as incentive for his thinking not possible to a former introspective and individualistic philosophy.

What of the leisure and freedom produced by improved machinery? If goods may be produced in less time, larger quantity and improved quality, and shorter hours and higher pay thus secured, what is done with the gains in time and funds? If pictures and radio are available several hours of each day, are they of a quality worthy of these marvelous scientific achievements? Have we progressed in such things as pictures, music and drama adequately to justify the distributional devices for which we have expended our more easily-earned incomes? By motors or aeroplanes we may visit and return in a day's time from places which were only points of "hear-say" to the past generation. In a day's flying time we may most comfortably traverse the distance of the Oregon trail which required five or six months of the most arduous labors amid great personal danger to men who are a still-living remnant of the age just passed. What worthy uses are made of the three-hundred mile automobile journey made in one day, or of other forms of our rapid and long-distance personal transportation?

When motor cars came they soon filled the city streets and country roads. The city streets and rural highways were laid out for the more leisurely people who walked or rode in buggies and wagons drawn by horses or even by oxen. Motors were operated by persons who were new to this complicated piece of applied science, by persons who could neither adequately control the machine at all times, nor properly safeguard those upon the streets or in other cars.

Thus in 1911 the fatal automobile accidents numbered 2,061. Fifteen years later, in 1926, the number was over 20,000, of which nearly one-third were persons under 15 years of age.

To keep reports of all fatalities caused by automobiles in the United States constantly recorded in a central office would keep one telegraph wire and a set of operators constantly occupied. The death list continues to grow.

Accidents caused by automobiles may serve as a type to illustrate the obligation imposed upon society and upon particular individuals concerned, through an acceptance of the results of scientific study. Human history does not record, so far as we know, any parallel illustrations of the adoption of the benefits of knowledge which so regularly exact death penalties and injuries in such high numbers. Inventions arising out of new scientific discoveries imply an obligation to provide appropriate controls. Studies have been made which show that children who rank in the lower part of the scale of native ability are more likely to have accidents than those of higher ability; also that efforts to teach accident prevention are least successful with those in

the lower part of the intelligence scale. Biologically, some one might say that it is well to allow modern machinery and ineffective means of protection to proceed on their present course, since the tendency is for accidents to occur to those in the lower intelligence rank. Possibly the race's intelligence may be improved by this type of artificial selection. But inadequate controls and regulations cause accidents to some of high rank. Also, society has not yet approved the removal of its less intelligent members, nor found sure ways of always pointing out who those members are. Certainly the family units to which the unfortunate ones belong do not approve this method of pruning the racial tree. No public claim has been made by the driver of an automobile which has killed a human being that the driver was vested with the right of improving the race by such methods.

The possession of science knowledge or of the appliances resulting from science knowledge must carry with it a knowledge of the proper uses of these possessions and a conviction of the moral as well as personal obligations accompanying these benefits. That education needed to sell and install an application of modern science must also implant a sense of responsibility commensurate with the new opportunities. It seems unwise and unsafe for knowledge and its power to be transmitted unless accompanied by an assurance of wholesome and upbuilding, not harmful and destructive, use of this power.

When the two-wheel bicycle came it occasioned astonishment. Some said, "It cannot work." It did. Soon thousands possessed the novelty, and parks, streets and roadways were filled with cycling humanity of all ages. Horses were sometimes frightened and some accidents occurred to human beings. Nowadays, messenger boys, store delivery men, children going to school, and others use the bicycle for regular work and for pleasure. It has found its place in service to society. It is understood and controlled with reasonable safety. Such will doubtless be the history of other useful appliances but as they increase and their use becomes more nearly universal, there will be imperative need for understanding their proper service.

Scientific and social development are not symmetrical. An overemphasis in one kind of development serves to emphasize the related needs, and usually indicates the nature of those needs. New devices for making pictures, speech and music available to all, create new demands for pictures, speech and music. Already there is wide-spread demand for better motion pictures, better radio addresses, better music for theatre and radio. The combination sight-and-sound presentation will make a new market for better drama and music. The radio at first held our thought as a marvelous novelty. We now accept it as a serviceable instrument and look for the best types of service. It is the novice, not the educated person, who will listen to just anything which radio waves will transmit. There is growth in the demand for and production of better uses of science appliances for improved social services.

Science, not to be discredited, must devise effective ways and means of developing, in its devotees first and in the whole people ultimately, a sense of moral obligation that will prevent the newly acquired knowledge and method of science serving base ends.

IV. The Science Subjects in Educational Programs. The energies and performances of schools and colleges may belong to either or both of two main headings.

One of these relates to learning how to do things—how to spell, read, write, compute, control oneself under varying conditions and circumstances, form valid judgments, cooperate with others, assume proper responsibility, lead when leading is needed or follow when worthy leadership is under way; these and others are involved in the disciplines by means of which useful and effective action may be decided upon and carried to proper conclusion. They are of supreme importance.

The other heading, not fully divorceable from the first, relates to the so-called fields or divisons of knowledge, the subject divisions which include the recorded experiences and ideas of the race—its recorded culture. Again those divisions are not fully separable from one another. Language and literature record and convey thought, experience, and ideals; history, geography and other social subjects, relate to men's living together under available physical, biological and human conditions; mathematics deals with measurement and computation, forces and relations; fine and industrial art includes the working world, and the efforts in graphic and musical presentation of life, thought and emotion; science deals with understanding, knowing and organizing physical and biological nature, with applications of both knowledge and method to new situations or new needs; indeed, through its method, science finds its way into each of the other divisions just as they find their way into it, for other subjects and disciplines become scientific as they become exact, orderly, organized, and as they clearly set what is known apart from or in perspective against what is not known. This second group, the divisions of knowledge or large subject groupings, are then to be examined, studied, made the immediate objectives of school and college effort, to be known by scholars who have scholarship, to be the foundation for living uses or for efforts to gain knowledge.

The major divisions or subjects of recorded culture seem necessary therefore for orientation of all who would possess even a general view of the race's background, of its present life, of the course now indicated by the tendencies of existing thought and action. It is not a question of finding a place in the program of studies for science at the expense of language and literature, or social subjects or of any other of the major divisions cited. It is a question of finding a place for and proper use of all these divisions, for none can be omitted.

But, language is specialized into many languages and literature into many types; mathematics has grown into many subdivisions; social sciences include several kinds of history, geography, civics, economics, and government; fine and industrial arts change their subdivisions with the statements of each professional advocate, and our scientific age has produced more than a score of science subjects, each of whose respective devotees would find a place for it in the educational program. In part, at least, the educational difficulties are produced by the very success of human effort to gain and organize knowledge. If there were not so many respectable and commendable subdivisions of knowledge, there would be fewer to contend for places

in the educational programs of schools and colleges. The condition is not peculiar to the sciences but perhaps is more acute in science due, first, to the prevailing habit of making education so largely linguistic, and, secondly, to the fact that in the unparalleled growth and use of science knowledge, more special divisions have occurred in it than in the other major divisions of knowledge.

Regarding the first factor just mentioned, further comment should be made. A study of individual student programs in secondary school and college usually shows that from one-half to two-thirds the time is given to linguistic studies. Numerous cases exist in secondary schools where a still larger proportion is given to languages and literature in some of the school years. It is not likely that any experienced teacher will maintain that the best language teaching fails to give growth in ideas in fields other than in language, but helpful as this may be, it cannot be claimed as one of the chief objectives of instruction in language and literature. Surely the thought-contributing, thought-provoking, and thought-creating subjects must have a large place in the program of studies if productive thinking and useful actions which are guided by modern ideas are the major objectives of education. It would be wholesome to education if an exhaustive investigation could be instituted with the end of producing an extended factual presentation of a proper balanced program of general education to include all the major divisions of inherited and growing knowledge.

Regarding the other factor cited in the second preceding paragraph, more must be said. The splendid achievements in specialized sciences are keenly appreciated and need all possible encouragement for further growth. Their devotees need to remember that the specialized subjects are built upon, grew out of and are supported by general scientific foundations. The upper stories of a building are reached by ascent from the foundational stories; and when descent is made into the common crowd of humanity, again the foundational regions are used. The common crowd has most contact with and is most conscious of the lower stories, but gains keen pleasure in occasional views into even the dizzy heights of a fifty-story structure, the upper parts of which are used by comparatively few. So it is with the more highly specialized sciences in their relation to those to be used for general education.

Nearly fifteen years ago, the National Education Association appointed a large committee to study the science situation in secondary schools. There were forty-seven members of this committee, various parts of the country and different science subjects being represented. They studied the secondary science situation throughout the whole country, and some members of the committee visited those schools in which serious efforts were being made to develop a coherent plan of science instruction. Resulting from the investigations of experimental efforts, and from the work of individuals and groups within the committee, an extensive report was prepared. This report was printed by the National Bureau of Education in Bulletin 26 of the 1920 series. This report definitely faced the tendency of having the different specialized sciences compete with one another for the available places in the program which were far too few to permit all to gain recogni-

tion. The report described and attempted to encourage the tendency toward a coherent and cumulative secondary sequence in science subjects. Certain of the schools which had conducted experiments had already reached most of the conclusions which the committee adopted, thus giving a measure of experimental guidance for the recommendations of the committee.

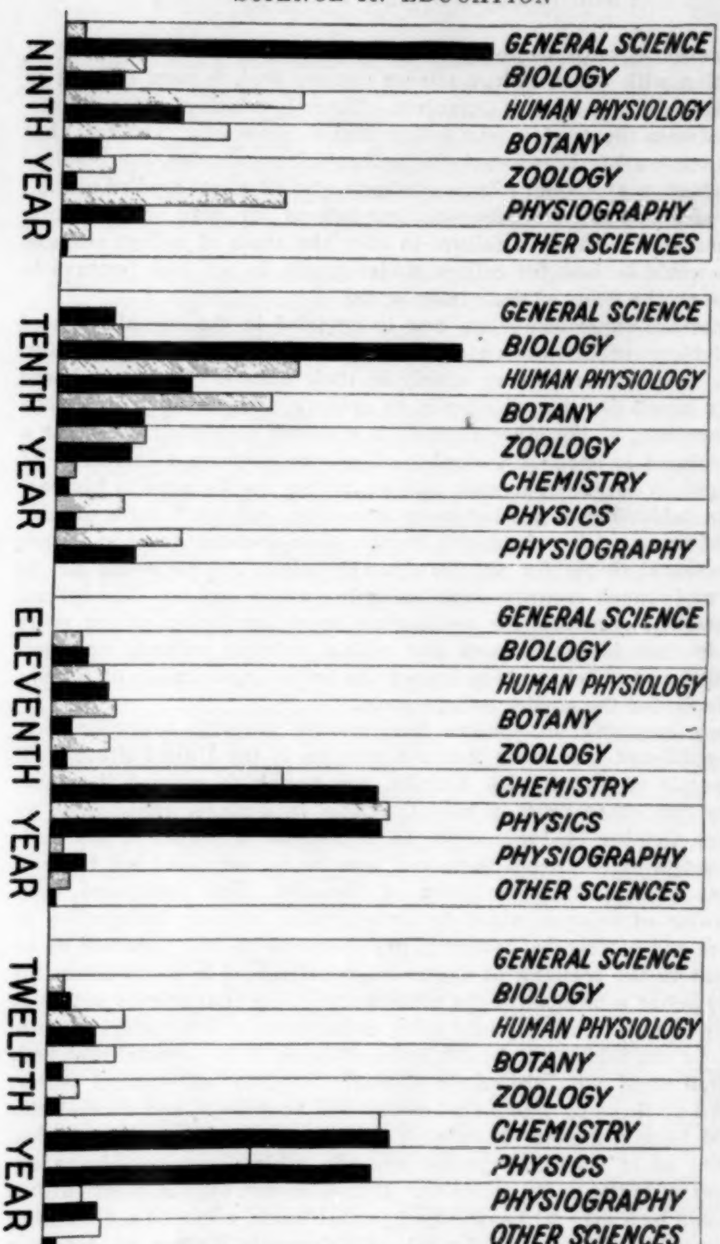
The recommendations presented in the report referred to involved: a discontinuance of competing specialized science subjects for the earlier high school years; a reduction of the number of specialized subjects which were made available in the upper years of secondary schools; a foundational two-subject sequence for all secondary school pupils, these consisting of significant topics or units in general science and general biology; a subsequent possibility of a full year of work in each of chemistory, physics, physiography or in a specialized biological science; an increased use in all secondary science of the kinds of science knowledge which a common citizen may understand, use, and learn to think about effectively with a corresponding reduction of such technical aspects as seem more properly to be deferred for later study by those who may take special courses in later years.

That the educational public will respond to well-considered recommendations such as those reported is shown by a study of the conditions in secondary sciences before and after the report was widely distributed. It so happened that a member of the committee had made a detailed study of a large number of secondary schools in the year 1908. The author, Dr. George W. Hunter was asked to make a similar study covering even a larger number of schools in 1923, but including all reporting in the study of 1908. In the chart given below we have the comparisons of the proportional representation of secondary sciences in the two periods.

From the diagram it appears clear that a secondary school sequence in science is developing, certainly for the first two years, and that in those years the special science subjects are tending to disappear. It is also clear that in the upper years the proportionate representation of Chemistry and Physics remain similar with some increase in the quantity of both. The other special sciences have decreased in the upper years.

In the recent extended development of the junior high school, the sequence plan for the sciences has been affected by having the sequence started earlier, that is, in the first or second junior high school year. Thus, a larger opportunity to elect special sciences in the upper years is produced. If a committee or commission somewhat similar to the one making the 1920 report could restudy the whole situation of science in the secondary schools, a report brought up to date would probably prove of value. We recommend to the United States Bureau of Education the consideration of such a piece of work.

The collegiate science situation is far from satisfactory. In the smaller colleges the practice still prevails of giving semester or one-year courses in each science. Thus a student in such a small college could, if he desired, secure college courses in each of several science subjects. In the larger colleges, the tendency is strangely to keep a science student in a given specialized department, for all or nearly all of his time which is available for science study. This seems very



Percentage of Students in Each Year of the High School Enrolled in the Various Science Subjects 1908–1922
Crosshatching 1908; Solid, 1923.

bad for first and second year college students in most cases. It would seem better to have the junior college years continue the types of science courses given in the best senior year high schools making them of strictly college grade and to insure that science students shall have a sound course in *each* of several specialized science fields. Then, senior college and university work could find a sound science foundation for preparation of vocational and research specialists.

However, it must be recognized, that a redirection of the part of education with which college science courses deal, is most difficult in American colleges as now organized. There is a lack of clear distinction between the services of a college and a university. The fact that specialization has begun early in college science courses has resulted in production of special science students who have not studied enough other sciences to give adequate foundations for safe specialization and has also resulted in failure to offer the kinds of college sciences which would be best for college students who do not look forward to science as the fields of their later work.

Important experiments are now being tried in the organization of introductory or orientation courses in science for the early college years. These courses vary widely in their nature. Some are based upon a single division of science, as geology (Dartmouth) or biology (Minnesota); at the other extreme is a course consisting of one or a few lectures in each of a number of science subjects (University of Chicago), a specialist in each subject giving the lectures in his particular field. The somewhat more attractive, but much more difficult plan of using a scientific, social, industrial or economic topic in science as a central theme for an introductory college course seems not to have made much progress in actual organization and use. The several encouraging programs for reorganization of the junior college years both in new junior colleges and within existing colleges and universities, seem likely to help toward the better organization of courses in science for the earlier college years.

Many important discussions dealing with scientific education have been published. To show that not only we in the United States, but the people of the British Empire, are trying to correct the same errors, we quote from a recent article in Nature, republished in Science, October 14, 1927: "Of the importance of science in any modern system of education there can here be no question; but there is danger of a certain confusion of thought. This insistence upon the value of science, aided by a confusion between instruction in science and a technical training, has obscured its true function as an element in the training of the average individual in preparation for his duties as a member of the community. Now that science enters so widely and so intimately into every department of life, especially into all questions relating to health and well-being, it is essential that both the individual who ultimately through the vote will control policy, as well as those by whom that policy will be framed and carried out, should have a general knowledge of the scope and aim of sciences, as well as of scientific method and the mode in which science envisages and attacks its problems. It is, however, beyond question that it should be a general knowledge in broad lines; a specialized training in some highly technical branch of science is neither needed, nor indeed is it desirable.

"As a medium of culture, the history of scientific discovery opens up to the imagination vistas of man's endeavor which place it in the front rank of humanistic studies. Through a general familiarity with the methods of scientific observation and experiment in the various branches of research there may be developed a critical attitude in judgment, a power of observation and a capacity for orderly ar-

rangement, while a knowledge of the questions with which science as a whole is and has been concerned, fosters the broad outlook, which in combination with these qualities, is essential in successful dealing with the problems of life. We doubt, however, whether much of the science teaching in the schools, either primary or secondary, could be regarded as science for citizenship instead of science for specialists, and we would welcome a movement which would broaden its scope and change its character."

The hopeful element is that the stereotyped science courses of the college are being replaced in the earlier years at least by new types, tentative at present but frankly experimental, looking toward a more satisfactory college science sequence. The whole problem needs careful study.

V. **Summaries of Types of Specific Studies Relating to the Educational Uses of Science.** There have been numerous studies which make a beginning of exact investigation from which we may know more accurately what may really be accomplished in science teaching. It is not desirable and space would not permit the presentation of even a bibliography of all these studies. It does, however, seem desirable to present summaries of selected sample studies. For this part of the report the committee has had the assistance of one who is especially competent to select the studies to be suggested as samples.*

In the brief space here available, the reviewer of these studies was asked to include types but by no means all of the valuable published statistical investigations which relate to the teaching of science. He has grouped these under the headings, the Learning Studies and the Curricular Studies. The first group includes those studies which involve the determination of the relative effectiveness of different methods, and the evaluation of certain teaching devices and practices. The second group includes those which involve the materials or subject matter which should be considered or stressed in teaching science. The extremely brief statements can do no more for each study than to suggest its nature and the kind of results secured from it.

A. The Learning Studies

Ayer, Fred C. "The Psychology of Drawing with Special Reference to Laboratory Teaching." Doctor's Dissertation. Baltimore, Maryland: Warwick and York, Inc,. 1916. From an elaborate series of five controlled investigations with high school and undergraduate and graduate students in university and normal school, the experimenter found evidence which supports his conclusion that the educational value of diagramatic drawings is distinctly superior to that of representative drawings as pupil records in laboratory work.

Colton, Harold S., "Drawing a Factor in the Training of Students in a Course of General Zoology." School and Society, Vol. XXIV, October 9, 1926, pp. 463-464. In an investigation with 249 students in college zoology, the experimenter finds evidence leading him to conclude that drawing should be featured in a science course because

* This part of the report has been prepared for the Committee by Francis D. Curtis, Associate Professor of Secondary Education and of the Teaching of General and Biological Science, University of Michigan. A more detailed and comprehensive presentation may be found in Dr. Curtis' volume, "A Digest of Investigations in the Teaching of Science in the Elementary and Secondary Schools." Philadelphia: P. Blakiston's Son & Co. 1926.

teachers can decidedly improve the quality of the student's science work by such emphasis.

Caldwell, Otis W., "Science Teaching in the Gary Public Schools." New York: General Education Board, 1919. In an elaborate investigation in which he used a number of ingenious and original tests, the experimenter secured extensive data indicating that seventh-, eighth-, and twelfth-grade girls surpass boys of the same grades in observation and discrimination; that the boys surpass the girls in interpretation and reading; and that elementary school boys do better than girls in recall and use of information.

Meister Morris, "The Educational Values of Certain After-School Materials and Activities in Science." Doctor's Dissertation. Out of Print. In a carefully controlled experiment running through five years, the experimenter found evidence supporting the conclusions that voluntary and uninstructed play with scientific toy outfits (Meccano, Chemcraft, etc.) give junior high school boys almost as good a knowledge and appreciation of environmental phenomena as regular class instruction in science, and that such play gives better constructive ability and a better control of physical and chemical elements in our environment. He concludes that such play encourages and stimulates activities giving first-hand experience with natural phenomena, and that it encourages originality and inventiveness and habituates boys to experimental procedure.

Beauchamp, Wilbur L. "Preliminary Study of Technic in the Mastery of Subject-Matter in Elementary Physical Science." Studies in Secondary Education, I, Supplementary Educational Monographs, No. 24, University of Chicago, January, 1923, pp. 47-87. In an investigation with high school pupils, the investigator secured evidence strongly indicating that specific training in four types of directed study which he describes, gives the pupils a better comprehension of subject-matter than study not thus directed. In a later investigation, (Supplementary Educational Monograph 26) this experimenter secured evidence which convinced him that scores in a silent reading test furnish a more reliable basis for grouping pupils into fast and slow groups, than scores in intelligence tests.

Watkins, Ralph Knupp. "The Technique and Value of Project Teaching in General Science." Doctor's Dissertation. Obtained from the author at University of Missouri, Columbia, Missouri. In a controlled experiment running through three years with classes in eleven high schools, the author secured objective evidence indicating that project teaching insures the attainment of more of the commonly accepted aims of the general science course than do the traditional methods of teaching.

Curtis, Francis D. "Some Values Derived from Extensive Reading of General Science." Doctor's Dissertation. Out of Print. In a series of controlled experiments in four New York high schools, the experimenter secured evidence showing that voluntary reading of scientific books which are not textbooks, contributes considerably to the pupil's knowledge of subject-matter of general science, and somewhat to his possession of scientific attitudes.

There have been so many investigations of the relative merits of the individual laboratory and the demonstration methods of instruc-

tion that a separate summary of each seems impracticable. The discussion is here confined, therefore, to mention of four of the most outstanding investigations in this field, together with an attempt to summarize the combined findings of all the studies on the problem to date:

Anibal, Fred G. "Comparative Effectiveness of the Lecture-Demonstration and the Individual Laboratory Method." Journal of Educational Research, May, 1925, Vol. XIII, pp. 355-365.

Carpenter, W. W. "Certain Phases of the Administration of High School Chemistry." Doctor's Dissertation. New York: Teachers College Contributions to Education, No. 191, 1925, Chap. IV, pp. 29-49.

Horton, R. E. "Some Measurable Outcomes of Individual Laboratory Work in Chemistry." Unpublished Doctor's Dissertation, Teachers College, Columbia University.

Kiebler, E. W., and Woody, Clifford. "The Individual Laboratory versus the Demonstration Method of Teaching Physics." Journal of Educational Research, January, 1923, Vol. VII, pp. 50-58.

The pooled results of some twenty research investigations of this problem seem to indicate that the demonstration method is worthy of a wider use as a method of laboratory instruction than it has customarily been given, since it is much more economical of time and money for equipment than the individual method, and since it seems to impart at least as good a knowledge of subject-matter as the other method. There is recent evidence to show, however, that there are a number of skills and habits which the student should acquire from his laboratory work which are imparted more effectively by the individual than by the demonstration method. It seems reasonable, therefore, that both methods should be given a prominent place in all our laboratory courses and that the combination of both should enable the teacher to offer a richer laboratory course, since the introduction of the demonstration method makes possible the giving of many more experiments in the same length of time, and also leaves a place for the performance by the pupils of those experiments which seem to offer the best media for imparting those specific skills and habits which the student may best acquire by that method.

The results of Carpenter's investigation of the advantages of working in pairs as compared with working individually seems to indicate that the latter method is, on the whole, superior, though it may not be sufficiently so to justify the additional expenditure of materials and equipment required for individual use.

For three recent critical discussions of this problem, see

Downing, Elliot R. "A Comparison of the Lecture-Demonstration and the Laboratory Methods of Instruction in Science," The School Review, November, 1925, Vol. XXXIII, pp. 688-697.

Riedel, F. A. "What, if Anything, Has Really Been Proved as to the Relative Effectiveness of Demonstration and Laboratory Methods in Science?" School Science and Mathematics, May and June, 1927, Vol. XXVII, pp. 512-519 and 620-631.

Curtis, Francis D. "Some Reactions Regarding the Published Investigations in the Teachings of Science, I. The Learning Studies." School Science and Mathematics, May, 1927, Vol. XXVII, 631-641.

Hurd, Archer W. "A Study of the Relative Value of the Topical versus the Problem Method in the Acquisition of Information on the

Subject of Heat in High School Physics, with its Implications." University of Minnesota, College of Education, Educational Research Bulletin, January 17, 1925, Vol XXXVIII. In a carefully controlled experiment, the author secured evidence to show that a method by which the class discusses assigned topics on the general socialized plan imparts general information better than one in which the pupils are assigned problems and subsequently in class hold "socialized discussions" on problem-solving.

Nash H. B., and Phillips, H. J. W. "A Study of the Relative Value of Three Methods of Teaching High School Chemistry." Journal of Educational Research, May, 1927, Vol. XV, pp. 371-379. In this controlled investigation, the experimenters used three methods: One in which the pupil worked through the term's work individually as fast as he could; one in which some of the work was demonstrated by teacher and pupils and some was done individually; and one in which the instructor made assignments but made no effort to check up on their preparation and in which the instructor demonstrated all the experiments while the pupils took notes. No drill was given with the first or third method, but extensive drill and review was given with the second. The results showed the best mastery of subject-matter with the third method, though the first method seemed best for the ambitious pupil, but poorest for the lazy pupil.

Beauchamp, Robert O., and Webb, Hanor A. "Resourcefulness, an Unmeasured Ability." School Science and Mathematics, May, 1927, Vol. XXVII, pp. 457-465. The investigators performed a carefully controlled experiment with high school juniors and seniors, in which they used a very ingenious "Test of Laboratory Resourcefulness" of their own invention. The results which they secured convinced them that pupils of little resource may make splendid records of achievement while resourceful students do not necessarily "reach the heights of achievement in physics and chemistry"; and that resourcefulness is an aspect of intelligence but is not measured by certain of the intelligence tests.

Stubbs, Morris F. "An Experimental Study of Methods for Recording Laboratory Notes in High School Chemistry." School Science and Mathematics, March, 1926, Vol. XXVI, pp. 233-239. In an "equivalent groups" experiment with high school seniors, the experimenter found evidence indicating that while the pupils learn more from writing their laboratory reports in complete form than from merely filling blanks and answering questions in spaces provided in their manuals, the gain seems scarcely worth the extra time and effort required by the more formal method of recording.

B. The Curricular Studies

Since the values of any curricular study lie chiefly in the actual curricular materials discovered or validated in the investigation, and since, therefore, no account of such a study which does not include these materials discovered can be of great practical service to makers of textbooks, courses, and curricula, the reviewer has deemed it practicable in the brief space limitations here imposed merely to list examples of various types of curricular studies by which materials suitable for inclusion in courses in science have been determined.

Harap, Henry. "The Education of the Consumer." Doctor's Dis-

sertation. New York: The Macmillan Co., 1924. The investigator analyzed a very great number of studies and statistical reports throwing light both upon "what the people actually do in the process of consuming food, clothing, shelter, and fuel," and upon the standards which should be known and enforced in connection with these commodities. The findings are expressed in the form of educational objectives.

Finley, Charles W., and Caldwell, Otis W. "Biology in the Public Press," New York: The Lincoln School of Teachers College, 1923. The investigators analyzed 3061 biological articles appearing in seventeen full months' issues of prominent and representative newspapers. They show the relative stress placed by the newspapers upon the various important phases of biology by listing the number, nature of the contents, and spaces used in the articles.

Ruch, Giles M., and Cossman, Leo H. "Standardized Content in High School Biology," The Journal of Educational Psychology, May, 1924, Vol. XV, pp. 285-296. The investigators secured more than two thousand final examination questions from 126 carefully selected teachers of biology representing all parts of the United States; they analyzed those for frequency and then condensed and classified them into three hundred items; they next had these items rated in importance by teachers of and authorities on biology.

Webb, Hanor A. "General Science Instruction in the Grades." Doctor's Dissertation. Nashville, Tennessee: George Peabody College for Teachers, Contributions to Education, No. 4, 1921. The investigator made a page by page analysis of 6638 pages in eighteen textbooks in general science, listing the topics treated under the various branches of science, and presented those data by elaborate analysis and statistical treatment.

Hopkins, L. Thomas. "A Study of Magazine and Newspaper Science Articles with Relation to Courses in Science in High Schools," School Science and Mathematics, November, 1925, Vol XXV, pp. 793-800. The investigator analyzed the scientific articles appearing in a month's issues of four daily Denver newspapers and of six issues of two scientific magazines, two home magazines, two weeklies, and two farm publications. He classified this material as theoretical or applied science, and listed it under appropriate topical subdivisions of the various branches of science.

Powers, Samuel Ralph. "A Vocabulary of Scientific Terms for High School Students." Teachers College Record, November, 1926, Vol. XXVIII, pp. 220-245. The investigator underscored all the words which appeared in two textbooks each in chemistry, physics and general science, six in general biology, three popular scientific books, and fifty magazine articles on science, but which did not appear in Thorndike's, The Teacher's Wordbook. By eliminating the compound words and others derivatives which would not cause difficulty if their roots were known, by deleting, also, compound words which did not convey a meaning different from that suggested by the words from which each was derived, and by eliminating all the words which did not appear at least ten times in the combined lists from all the sources, the investigator secured a final list of 1828 important uncommon words which occur in the science courses studied.

Pollock, C. A. "Children's Interests as a Basis of What to Teach in General Science." Ohio State University Educational Research Bulletin, January 9, 1924, Vol. III, pp. 3-6. Curtis, Francis D. "An Investigation of Adults' and Children's Scientific Interests." Out of print. Curtis, Francis D. "A Study of the Scientific Interests of Dwellers in Small Towns and in the Country." Peabody Journal of Education, July, 1927, Vol. V. In each of these three studies, the investigators made a series of analyses of questions submitted by individuals who were asked to submit questions about the phases of science in which they were most interested. In all three studies combined, 8448 questions submitted by 1708 children, and 4878 questions submitted by 1091 adults, were analyzed.

Herriott, M. E. "One Influence of Out-of-School Activities in Determining the High School Physics Curriculum." School Science and Mathematics, January, 1927, Vol. XXVII, pp. 56-60. Boys and girls, together with men and women from thirty-seven occupations, were asked to indicate the extent to which 576 activities involving rather definitely ascertainable principles and elements of physics entered into their lives.

Glenn, Earl R., and Brookmeyer, Ivan L. "An Analysis of the College Entrance Examinations in Physics." School Science and Mathematics, May, 1923, Vol. XXIII, pp. 459-470. The investigators independently analyzed all the Old Plan College Entrance Board Questions in physics from 1911 to 1922, and the Comprehensive Plan Questions from 1916 to 1922, to ascertain the facts or laws of physics required for a correct answer to each question.

Koos, Leonard V. "Overlapping in Chemistry." The Junior College. Research Publications of the University of Minnesota, Education Series, No. 5, May, 1924, pp. 474-493. To determine whether there is an overlapping of high school and college courses in chemistry, the investigator compared the textbook and laboratory manual content of high school and college courses, along with the amount of supplementary materials used, the methods, the size of sections, the length and numbers of periods represented by twenty-six high schools and forty-one colleges in the north-central states.

Downing, Elliot R. "Children's Interest in Nature Materials." The Nature Study Review, December, 1912, Vol. VIII, pp. 334-338. The investigator analyzed 447 questions and 295 observations voluntarily written to St. Nicholas by 301 boys and 441 girls, and published from November, 1899, to April, 1912, under the departments, "We Will Ask St. Nicholas About It," and "Because We Want to Know."

The above represent but a beginning in the application of the objective scientific method to the problems of science teaching. Such investigations must be multiplied and verified by those truly interested in the scientific solution of such questions.

VI. **Those Who Teach Science.** As previously stated we are in a period of science knowledge, of science ideals and of science controls so far as concerns material progress, possibly also as concerns industrial, economic and social progress. Those who possess or those who can direct the uses of science knowledge will possess the controls of comfort and well-being. Possibly the minority of citizens now have

enough science knowledge to enable their knowledge to become power, but through our program of universal education the children of all the people are rapidly becoming ambitious to participate in the real or supposed benefits which modern knowledge and methods give to human welfare.

As yet educational systems are not so organized, staffed, or directed as to give all young people what they most need. This is partly because educational procedures are too hasty, in so much hurry to achieve that they omit those arduous endeavors by means of which lasting results may alone be incorporated into personal practices. Education often fails, however, because it so often misses the main purpose of teaching modern scientific thought and controls. Too often the ends sought are economic solely, or for personal gains in power. Of course, education must use real work of the world, real facts of science, as the materials for study. Science is not primarily for the purpose of building dynamos, understanding the radio, for producing more corn or better hogs, but for producing better human beings. But better people can be produced only by causing them to think, to work, to idealize the genuine aspects of their lives—but the ultimate purpose is better lives not better crops or larger bank accounts. Science properly studied is not likely to fail to produce better material benefits. The danger is in its possible failure to produce more than material benefits.

The social, individual and community obligations which accompany growth in knowledge or power need keener definition than has been common. The fundamental obligation to think from and upon a basis of facts is none too commonly recognized. The responsibilities accompanying gains in scientific controls are almost omitted from the common discussion of science education. Possibly science teaching, of all teaching, most needs such redirection because science is so largely responsible for production of coordinated units of new knowledge which, when unguided by proper knowledge and purposes, must do harm instead of good. We may observe the uses of the radio everywhere, without adequate standards of development of things really worth hearing. Thus the radio, one of the scientific wonders of our times, may in its results mean intellectual dissipation. Automobiles when operated by irresponsible drivers mean injury or death to innocent persons. Chemical knowledge without moral responsibility means destructive uses of science, biological knowledge of new life and its origin and control, without moral responsibility means avoidances of parental obligation. In the present stage of social uses of knowledge, what could be accomplished by bringing up a generation of young people who possess a whole and unified point of view of what modern science knowledge is for, what it really means in human development, not for gains in goods but gain in ideals and controls in character?

Science teachers need more than point of view—indeed, like their pupils, they gain point of view from science study. Most have too little real science study. It is not a proper part of this report to outline programs for collegiate and professional training of science teachers. We wish to record our judgment that more science study is essential to the improvement of science teaching. But this larger

amount of science study for those who are to teach needs to be done with its teaching uses in mind. Like the advanced academic work expected of one who is preparing for the professions of law or medicine, so should the necessary additional science study be both taught and studied with reference to its uses in education. The college and graduate courses in law relate to the lawyer's profession; in medicine, to the physician's study and practice; in business, to the thought and practices of commercial and industrial life. We need a similar organization and use of science courses for those who are to teach. Not less exacting courses are needed, but redirected courses relating to the professional uses of science in education. In the most favorable situations a satisfactory amount of elementary sciences may now be secured in junior and senior high schools, and in college. One may now take two years of science in junior high school; from one to three years in senior high school and from one to four years in college. If we could count regularly upon four years, or more, of science study during the six years of junior and senior high school, and upon two years, or more, during the four years of college, and could then add a graduate year given to further professional study as well as to added academic science study, a reasonable scholastic preparation might be made for science teaching. Such a program is possible with conditions as they now exist. To carry out the desired professional program will require that college courses shall touch various sciences with a professional outlook, instead of restrict the student to one or a few subjects with only the research outlook. We need a detailed study of the whole program of science courses as well as professional courses made available to those who teach science, to the end that the most effective plans may be made clear for general guidance in teacher training. The committee suggests such a study as a part of the work of some organization or council later to be formed. Science teaching is not limited to those who teach and study in classrooms. In recent years other highly important agencies have developed. Possibly the people in general have received their best science teaching from newspapers, magazines, books and lectures. That the public welcomes such teaching is evidenced by the wide uses made of such publications as "The Science News Letters," a weekly summary of current science, the "Popular Science Monthly," the "National Geographic Magazine"; by the successful and rapidly increasing supply of books popularizing science knowledge; and by the insistent demands for understandable public lectures upon the achievements of modern science. Popular but scientifically sound writing and speaking about the work of scientists opens a large vocational opportunity for young persons who will train themselves especially for such endeavors.

A more thorough-going preparation in the fundamentals of science is needed by all who aspire to teach it.

VII. **Those Who Have Developed Science.** In a program of liberal education in science it is recommended that attention be given to the personalities of the men of science who have through their researches contributed to the field. In this as in literature, history and other fields, efforts to humanize knowledge are dependent in large part for success upon study and understanding of the personalities of

those who are or who have been the outstanding contributors to them. Culture can hardly be divorced from personalities. It follows, therefore, that the cultural values of science should be found most clearly exemplified in the culture of those who have developed it. The truth of this contention seems self-evident and for this reason no argument is given to support it. This division of the report represents an effort to clarify in some measure what is meant by cultural or liberalizing values of science and to suggest some of the ways in which these potential and in large measure neglected values may be made accomplishments.

This period is distinguished from preceding ones by the fact that it is an age of applied science. Practical science has completely transformed our manner of living. On the liberal side this period is not clearly distinguished from others which have preceded it. The mass of our population is still victim of tradition, prejudice, and superstition and unmindful if not unconscious of the methods of working which scientists have developed and employed in their researches to reveal truth. Neither the methods of scientific study nor the personalities of those who apply them have been objectified with sufficient clarity to make them functional in general education. It is true that one finds in the definitions of objectives of science teaching which have been stated throughout the past seventy-five years many references to the scientific method, and time and again elements of it are exemplified in the instructional efforts of masterful teachers who are themselves appreciative of its meaning. But unfortunately such cases are relatively rare. It is a common charge and it cannot be denied that science teachers generally are failing to transmit to liberal education any clear understanding of the scientific methods of work and study or of the scientific attitudes. Teachers should be conscious of their responsibilities with respect to these as outcomes from their teaching and should be able to define some means for meeting these responsibilities.

Educational psychology teaches that effective learning is conditioned upon clear definitions of the objectives, that is of the learning outcomes, that are set for accomplishment. When the criterion of clarity of definition is applied to educational objectives which incorporate reference to the scientific method the inadequacy of these statements becomes evident. The assumptions which are the basis of much that is done in curriculum work in science and in teaching are that there is but one scientific method and but one scientific attitude; that the scientific attitude is but a simple mental adjustment which may be readily made even by immature thinkers; and that when once made it is readily transferred to any and all problem situations which the learner may face. More effective accomplishment requires that the objectives be more clearly defined. It is proposed here that clarity may be attained by objectifying incidents in the lives of scientists selected to portray the particular methods of investigation and study which they have used, and incidents which portray the ideals, ambitions and character traits which are associated with their work. The elements of the scientific methods and of the scientific attributes shall be objectified by seeing them in the reports of the activities of men of science while they were at work. At the same time the inner

motives, that is the culture, of the scientist may be in some measure objectified through the study of his character as revealed in his biography. It seems that the schools and society are absorbing the output of scientific work, that is the practical application, much more rapidly than they are absorbing the culture of the men who contributed it. Liberal education is incomplete without this culture. These points may be further clarified by reference to illustrations.

The method of investigation used by Robert Koch and by means of which he determined the causative organism of anthrax lends itself to analysis and illustrates a method of scientific study. About 1850 it was discovered that a particular form of bacterium (a bacillus) was present in the blood of sheep and cattle afflicted with anthrax. There was no exception to this observation. When an animal showed symptoms which were identified as anthrax the particular bacillus was always present in that animal's blood. Was there a cause and effect relation between these two concomitant phenomena? Was the bacterium the cause of the disease? Robert Koch was challenged by these observations and set up as an hypothesis that the bacillus was the cause of the disease. He then turned to the task of establishing or disproving the truth of his hypothesis. He must have recognized that there were a considerable number of alternative possibilities, such as, that the organism in the blood is a result from the disease rather than a cause; that it was attendant upon some other condition which was the real cause; or, possibly, that there was no relation between the two things. In order to test the hypothesis it was necessary to separate the organism from the other things in which it was associated,—that is, reduce his experiment to one in which there was but a single variable. By application of his experimental technic he (1) separated the organism from the animal's blood; (2) grew it in pure culture; (3) inocculated a healthy animal with the organism obtained from pure culture; (4) by this means caused the development in the healthy animal of the symptoms of anthrax; and (5) finally recovered the organism from the blood of the experimental animal. He thus established beyond any reasonable doubt the truth of his hypothesis. This is said to have been the first conclusive proof that any specific disease is caused by a specific organism. Koch's method of study is essentially the same as the one used today in investigations of the causes of disease thought to be the result of bacterial infection.

The importance of such an analysis as this in a program of liberal education is that it reveals with some clarity the elements of a method of scientific study. There was first an observation of concomitant phenomena. This observation was a challenge to Koch to determine the cause and effect relation between the two phenomena. He controlled his investigation by reducing it to one in which there was but a single element, namely, the bacterium growing in pure culture. The method of study was successful because he established the truth of his hypothesis. Incidently his work was of large social significance for it developed a technic which has had extensive application in studies which have contributed enormously to the reduction of suffering from bacterial disease. At the time his study was underway relatively few individuals were questioning the cause

of disease. His work was unique, but further application of his method has resulted in much wider acceptance of the notion that diseases are resultant from causes and that science has done a great deal to determine the causes and to establish controls of them.

In this brief presentation it should be added that Koch's discovery did not come from a single experiment, but rather that it was an outcome from four years of intensive study by an investigator equipped with the best scientific training that his age could give. It is of little consequence that he was a German, a practicing physician, that he was born in 1843, and that other events transpired as recorded in his biography. The important thing is the method of scientific study which he developed and applied to determine the cause and effect relation between anthrax bacillus and anthrax disease. The liberally educated person should understand also that other diseases are resultant from specific bacterial infection. He should come to understand that all happenings are resultant from causes, and in his study of problems which come within his experience he should attempt to come to an understanding of the causes and, if possible, to control them. The significance of these considerations is more evident to the student after he has gone vicariously through the experiences of Koch and other pioneer scientific investigators.

Another method which is characteristic of scientific study and thought may be illustrated by reference to Dalton and his atomic theory. A significant feature of his contribution is that he was able to see the interrelation of independent and seemingly exclusive observations and to formulate a series of generalizations which show the correlation between them. His theory, that is his explanation, has stood the test of time and the persistent scrutiny of scientific investigators as a true portrayal (even thought it is incomplete) of the nature of matter and of the nature of chemical change. The elementary nature of matter and the distinction between elements and compounds had been suggested by Robert Boyle. Lavoisier had established the principle of the indestructibility of matter in chemical changes. Dalton himself had proposed from experimental data the law of multiple proportion and he had established the law of defiinte composition. Dalton was now challenged by the question, What is the nature of matter? How can these things be so? From these observations (and some others) he formulated the essential elements of the atomic theory. This is a marvelous illustration of creative thinking. The program of liberal training should take the student vicariously through the experiences which guided Dalton in its accomplishment.

These illustrations of incidents which illustrate applications of scientific methods of work and thought might be extended indefinitely. They may be seen in the lives and activities of all successful men of science. These illustrate attributes which characterize the methods of scientific investigation and they are attributes which influence the culture of men of science. Some of these should function in liberal thought and there is good reason to believe they could be made to function much more generally if they were clearly defined and incorporated in the program of liberal training. This division

of the report is offered as a suggestion of ways and means for incorporating the culture of the men of science into the program of cultural or liberal education. Effective accomplishment of the objectives here suggested will require educational research which will be directed toward a determination of the elements of scientific methods which may be functional in liberal thought and research in the form of learning studies which will reveal effective procedures for mastery of these elements.

Science as method is quite as important as science subject matter and should receive much attention in science instruction.

The committee offers the following **recommendations:**

(a) That some organization of national scope, such as the United States Bureau of Education, or the Research Division of the National Education Association, be asked by this committee to undertake a comprehensive and intensive study of the situations, tendencies and needs of science instruction in educational systems.

(b) That the services of a field secretary be secured, to work with existing agencies, to distribute information on research in science education, to stimulate further research, to operate as a sort of clearing-house agent and to continue the organizing of new groups of science teachers, writers for popularization of science, etc. This field secretary should work under the guidance of the Committee on the Place of Science in Education, or under the guidance of a national council of science teachers as soon as such a council is formed.

(c) That a national council of science teachers be organized to advance science teaching, to increase public appreciation of science and to secure for science teachers increased facilities and a wider usefulness. The services of a field secretary would be very useful in the organization of such a council.

PROBLEM DEPARTMENT.

Conducted by C. N. Mills,
Illinois State Normal University.

This department aims to provide problems of varying degrees of difficulty which will interest anyone engaged in the study of mathematics.

All readers are invited to propose problems and to solve problems here proposed. Drawings to illustrate the problems should be well done in India ink. Problems and solutions will be credited to their authors. Each solution, or proposed problem, sent to the Editor, should have the author's name introducing the problem or solution *as on the following pages.*

The Editor of the department desires to serve its readers by making it interesting and helpful to them. Address suggestions and problems to C. N. Mills, Illinois State Normal University, Normal, Ill.

LATE SOLUTION.

1005. *H. G. Ayre, Waukegan, Ill.*

SOLUTIONS OF PROBLEMS.

1007. *Proposed by the Editor.*

Any number (N equal or less than 105) is divided by 3, 5, and 7, giving remainders R_1, R_2, R_3, respectively. A is the smallest number, when divided by 3 and 5, gives the remainders R_1 and R_2. When A is divided by 7 the remainder is R^1.

Prove

$$N = (R_3 - R^1)\,15 + A, \text{ when } R_3 \geq R^1,$$

and

$$N = (7 + R_3 - R^1)\,15 + A, \text{ when } R_3 < R^1.$$

Solved by the Proposer.

By arranging the schedules for the remainders for the divisors 3 and 5 and noting the sequence of remainders for the divisor 7, one is able to see that the above expressions in the sign of grouping represent the number of terms preceding the required number. An example for each formula will be given.

	3	5	Number	10	25	40	55	70	85	100
Rem.	1	0	Rem. for 7	3	4	5	6	0	1	2

For the selection $\begin{matrix} 3 & 5 & 7 \\ 1 & 0 & 5 \end{matrix}$, $A = 10$, $R^1 = 3$, and $(R_3 - R^1) = 2$, hence there must be added to 10 two times fifteen, giving $N = 40$.

For the selection 3 5 7, $A = 10$, $R^1 = 3$, and $(7 + R_3 - R^1) = 5$, hence there must be added to 10 five times fifteen, giving $N = 85$.

The above formulas can be established by means of modular congruence theory, but another method of determining the number N can be used. We will call the method "Key Numbers."

Let A be the smallest multiple of 35 giving a remainder of unity when divided by 3, in this case $A = 70$. Let B be the smallest multiple of 21 giving a remainder of unity when divided by 5, in this case $B = 21$. Let C be the smallest multiple of 15 giving a remainder of unity when divided by 7. Denoting the remainders R_1, R_2 and R_3 for the divisors 3, 4, and 5, respectively, the required number N is the remainder when $(R_1A + R_2B + R_3C)$ is divided by 105. The proof of this statement is not difficult either by means of elementary arithmetic, or by means of modular congruences.

This method can be generalized for any set of divisors prime to each other.

1008. *Proposed by B. M. Lindemuth, Defiance, Ohio.*

Find the two sides of a right triangle and the hypotenuse of the right triangle if the sum of the two sides is 25 feet, and the altitude to the hypotenuse is 5 feet.

I. *Solved by Robert Hechtman, Lewis and Clark H. S., Spokane, Wash.*

Let x and y be the sides, and z the hypotenuse. Then

$$x + y = 25 \qquad (1)$$
$$x^2 + y^2 = z^2 \qquad (2)$$
$$x/z = 5/y \qquad (3)$$

Substituting the value of z from (3) in (2) we get $25x^2 + 25y^2 = x^2y^2$ (4)
Squaring (1) and subtracting from (4) we get

$$x^2y^2 + 50xy - 15625 = 0.$$

Solving, $xy = 102.48$, and using (1) gives $x = 5.17$ ft., $y = 19.83$ ft. and $z = 20.5$ ft.

II. *Solved by P. H. Nygaard, N. Central H. S., Spokane, Wash.*

Let X be one side and (25-X) the other side. The segment of the hypotenuse adjacent to X is the square root of $(X^2 - 25)$, and the segment of the hypotenuse adjacent to (25-X) is the square root of $(X^2 - 50X + 600)$. Applying the theorem that the altitude is a mean proportional between the adjacent segments of the hypotenuse, and simplifying the expression, gives

$$X^4 - 50X^3 + 575X^2 + 1250X - 15625 = 0.$$

Solving by Horner's method, $X = 5.17$ ft., $(25 - X) = 19.83$ ft., and the hypotenuse equals 20.495 ft.

Also solved by *I. N. Warner, Platteville, Wis.; Smith D. Turner, Cambridge, Mass.; E. de la Garza, Brownsville, Texas; and George Sergent, Tampico, Mexico.*

1009. *Proposed by P. H. Nygaard, N. Central H. S., Spokane, Wash.*

The sides of a triangle are 5, 6, 7. Find the three angles of the triangle by use of the *Law of Sines* and the fact that the sum of the three angles of a triangle is 180°.

Solved by Smith D. Turner, Cambridge, Mass.

Let A, B and C be the vertices opposite the sides of lengths 5, 6 and 7, respectively.

$$\text{Sin } B = 6/7 \text{ Sin } C \qquad (1)$$
$$\text{Sin } A = 5/6 \text{ Sin } B. \qquad (2)$$

(2) may be written

$$\text{Sin } [(180° - B) - C] = 5/6 \text{ Sin } B,$$

or $\quad \text{Sin}\,(180° - B)\,\text{Cos}\,C - \text{Cos}\,(180° - B)\,\text{Sin}\,C = 5/6\ \text{Sin}\,B,$

or $\quad \text{Cos}\,C + \text{Cot}\,B\,\text{Sin}\,C = 5/6,$

or $\quad \text{Cos}\,C + \sqrt{13/36 + \text{Cos}^2 C} = 5/6.$

Solving the last equation gives Cos C = 1/5, hence C = 78° 27′ 47″.
Using (1) and (2) we find A = 44° 24′ 53″, and B = 57° 7′ 20″.

Also solved by *Anna M. Svec, Alma, Wis.; R. T. McGregor, Elk Grove, Calif.; George Sergent, Tampico, Mexico;* and the *Proposer.*

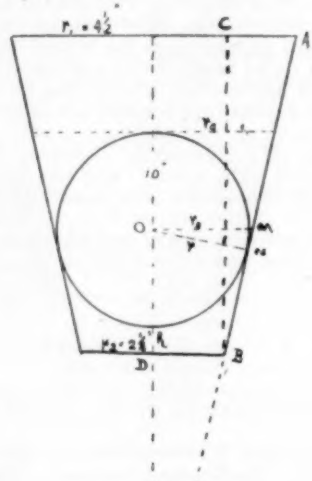
1010. *Proposed by E. T. Boynton, Richmond, Ky.*

A tin vessel, having a circular mouth 9 inches in diameter, a bottom 4½ inches in diameter, and a depth of 10 inches, is ¼ part full of water. What is the diameter of a ball which can be put in and just covered with water?

Solved by E. A. Hollister, Pontiac, Mich.

This problem is a study of the frustums of a cone whose volumes are obtained by the formula

$$V = \frac{\text{pi}\,H}{3}(R_1^2 + R_1R_2 + R_2^2).$$



For the whole vessel H = 10, $R_1 = 4\frac{1}{2}$, and $R_2 = 2\frac{1}{4}$, which gives for its volume 118.125 pi cu. in. The amount of water in the vessel is (118.125 pi)/4 cu. in. If this volume is added to the volume of the sphere it should equal the volume of the frustum whose upper radius is R_4 (See figure), lower radius 2¼ and height $(2R + h)$, R being the radius of the required sphere. Hence,

$$\frac{4\,\text{pi}\,R^3}{3} + \frac{118.125\,\text{pi}}{4} = \frac{\text{pi}\,(2R + h)}{3}\,[(9/4)^2 + 9/4R_4 + R_4^2]. \quad (1)$$

$AB = 41/4$; $R_3 = 41R/40$; $h = 32R/9 - 10$; $R_4 = 5R/4$.

Substituting the above values in (1) and multiplying by 432/pi, we get after simplifying

$$674\ R^3 = 20047.5.$$

Hence R = 3.0984 in. and the diameter is 6.1968 in.

Also solved by *George Sergent, Tampico, Mexico; S. M. Turrill, Crane Junior College, Chicago, Ill.;* and the *Proposer.*

1011. *Proposed by E. de la Garza, Brownsville, Texas.*

Show that for values of N greater than 1, the following expression is a multiple of 360:

$$N(N^2 - 1)\ (4N^2 - 1)\ (5N + 6).$$

Solved by J. Murray Barbour, Aurora, N. Y.

The expression may be written

$$N(N-1)\ (N+1)\ (2N-1)\ (2N+1)\ (5N+6).$$

If N is even, so is $(5N+6)$ and one number is divisible by 4. If N is odd, both $(N-1)$ and $(N+1)$ are even, and one is divisible by 4. In either case 8 is a factor.

If N is divisible by 3, so is $(5N+6)$. If $(N-1)$ is divisible by 3, so is $(2N+1)$. If $(N+1)$ is divisible by 3, so is $(2N-1)$. Since one of these possibilities is true, 9 is a factor.

Suppose that N, $(N-1)$, or $(N+1)$ is not divisible by 5. Then either $(N-2)$ or $(N+2)$ is divisible by 5. If $(N-2)$ is divisible by 5, so is $(2N+1)$. If $(N\ 2)$ is divisible by 5, so is $(2N-1)$. Since one of these five possibilities is true, 5 is a factor. Hence $8\times9\times5 = 360$ is a factor.

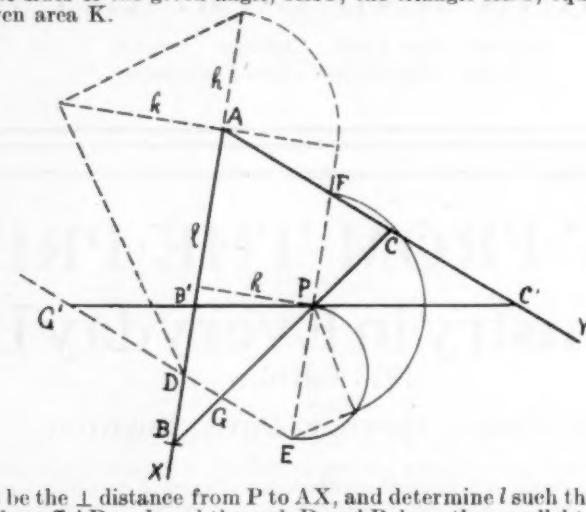
Also solved by *P. H. Nygaard, N. Central H. S., Spokane, Wash.*; *F. A. Cadwell, St. Paul, Minn.*, using the idea of *Functional Equations*; and the *Proposer*.

1012. *Proposed by W. W. Ingraham, Williamstown, W. Va.*

Through a given point P, within a given angle, to draw a line which shall form with the sides of the angle a triangle of given area (Wells Plane Geometry).

Solved by George Sergent, Tampico, Mexico.

Supposed the problem solved, and let BC be the line through P, forming with the sides of the given angle, XAY, the triangle ABC, equivalent to the given area K.



Let h be the $\perp$ distance from P to AX, and determine l such that $lh = K$. On AX lay off $AD = l$, and through D and P draw the parallel to AY and AX, respectively, thus forming the parallelogram ADEF, equivalent to K.

Let G be the intersection of BC and DE. The pentagon AFPGD is common to the triangle and the triangle ABC. The triangle PEG is equivalent to the sum of triangle PFC and DBG. These three triangles are similar. Hence

$$\frac{PFC}{PF^2} = \frac{DBG}{DB^2} = \frac{PEG}{PE^2} = \frac{PFC+DBG}{PF^2+DB^2}, \text{ and } PE^2 = PF^2+DB^2.$$

PE is the hypotenuse of a right triangle whose sides are PF and DB. PF is known, and $PE = l-PF$; this triangle can be constructed, and DB determined. Join B and P, and produce to C on AY. ABC is the required triangle.

In a similar manner, a second triangle AB^1C^1 can be constructed if PE is greater than PF.

Also solved by *E. de la Garza, Brownsville, Texas; Smith D. Turner, Cambridge, Mass.*; and the *Proposer*.

PROBLEMS FOR SOLUTION.

1025. *Proposed by E. de la Garza, Brownsville, Texas.*

Given a triangle ABC, to draw a line DE, limited by the sides of the angle A, such DE = DB = EC, D being on AB.

1026. *Proposed by Volney Weir, Versailles, Indiana.*

A line through the centers of two given unequal circles intersects the common external tangent at P, and the two circles at A, B, C, and D. If a secant is drawn from P. intersecting the circles in W, X, Y, and Z, taking the points in order from right to left, prove that $PW \times PZ = PX \times PY$. (Newall and Harper, Plane Geometry.)

1027. *Proposed by the Editor.*

Find the integral values for a, b, and c, such that each of the following expressions is the square of an integer: (a^2+b^2), (a^2+c^2), and (b^2+c^2).

1028. *Proposed by S. M. Turrill, Crane Junior College, Chicago, Ill.*

Upon each side of a scalene triangle construct (outwardly) equilateral triangles. Find the center of gravity of each of these triangles. Prove by methods of Plane Geometry that the center of gravity points determine an equilateral triangle.

1029. *Proposed by L. S. Guss, Austin H. S., Austin, Minn.*

Three circles, A, B, and C are tangent externally. From the point of tangency of A and B, two lines are drawn, one through the point of tangency of B and C, the other through that of A and C. These lines cut the circle C at the points M and N. Prove that MN is the diameter of the circle C.

1030. *Proposed by George Sergent, Tampico, Mexico.*

For any given triangle, ABC, prove that

$$\frac{\sin(A-B)}{\sin(A+B)} = \frac{a^2-b^2}{c^2}.$$

THE DETROIT MATHEMATICS CLUB.

By MELVIN J. GILLARD.

The Detroit Mathematics Club is a club composed entirely of mathematics teachers and administrators. The purpose of the club is to promote the specific interest and latest thought in the field. To this end a program obtains which brings before the club speakers who are outstanding leaders in the promotion of mathematical science on the secondary school level. In general, there are five meetings which comprise a year's program. For each of the last two years, the final meetings were given over to several short discussions of mathematical topics of genuine local interest. Local teachers and administrators present such discussions. On this year's program there appeared Dr. Karpinski of the University of Michigan and Dr. Breslich of the University of Chicago. The final meeting of this year obtains late in April and the program is as follows:

1. "The Winnetka Plan." Miss Esther H. Robinson, Mathematics Teacher, Hutchins Intermediate.
2. "Individualization of Instruction." Mr. Paul T. Rankin, Assistant Director, Department of Instructional Research, Board of Education.
3. "The Unit Plan of Instruction." Mr. Isaac Devoe, Head of the Mathematics Department, Highland Park High.
4. "The Dalton Plan." Mr. Manley E. Irwin, First Assistant Supervisor, Department of Instructional Research, Board of Education.
5. "Intermediate School Mathematics in Detroit: Tendencies and Articulation." Mr. C. L. Thiele, Assistant Director of Exact Sciences, Board of Education.
6. "The N. E. A. in Boston, February, 1928." Mrs. Amy L. Coats, Mathematics Teacher, Northwestern High School.

The membership of the club has been steadily increasing. This year it totals just over two hundred. The fee is one dollar. As an experiment, the meetings on this year's program were held in different schools. About one hundred and twenty-five teachers and administrators attended the last meeting so it is believed the interest has been retained, if not increased, by the experiment.

BOOKS RECEIVED.

Fundamentals of Modern Chemistry, by Herbert R. Smith, M. A., Lake View High School, Chicago, and Harry M. Mess, B. A., Nicholas Seen High School, Chicago. Cloth. Pages vii+266. 12.5x18.5 cm. 1928. Henry Holt and Company, New York.

A Guide to the Wild Flowers, by Norman Taylor, Curator, Brooklyn Botanic Garden. Cloth. Pages x+357. 12x18.5 cm. 1928. Greenberg, Publisher, Inc., 112 East 19th St., New York. Price $3.00.

General Chemistry, by Azariah T. Lincoln, Professor of Chemistry, Carleton College and George B. Banks, Professor of Physical Science, Niagara University. Cloth. Pages xxii+681. 15x22.5 cm. 1928. Prentice-Hall, Inc., New York. Price $3.50.

Introductory Mathematics, by Joseph Eugene Rowe, Ph.D., Professor of Mathematics in the College of William and Mary. Cloth. Pages vi+285. 15x23 cm. 1927. Prentice-Hall, Inc., New York. Price $2.50.

The Early Mathematical Sciences in North and South America, by Florian Cajori, Ph.D., Professor of the History of Mathematics, University of California. Illustrated. Cloth. 156 pages. 13x20 cm. 1928. Richard G. Badger, Publisher, The Gorham Press, Boston.

Physics for College Students, by A. A. Knowlton, Ph.D., Professor of Physics, Reed College. First Edition. Cloth. Pages xix+641. 23x14.5 cm. 1928. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $3.75.

Algebra Review Exercises, by Josiah Bartlett, Gilman Country School, George W. Creelman, Hotchkiss School, Cecil A. Ewing, Tome School, Ernest E. Rich, Lawrenceville School, George R. Wilson, Taft School. Cloth. Pages vi+151. 12x18.5 cm. 1928. Ginn and Company, 15 Ashburton Place, Boston. Price $1.00.

Workbook for Grade V to accompany The Buckingham-Osburn Searchlight Arithmetics Book Three, Part I, by B. R. Buckingham, Director of the Bureau of Educational Research, Ohio State University and W. J. Osburn, Director of Educational Measurements, State Department of Public Instruction, Madison, Wisconsin Paper. 98 pages. 20x27.5 cm. 1928. Ginn and Company, 15 Ashburton Place, Boston. Price 36 cents.

Key Experiments in General Science, A Students Laboratory Notebook and Manual, by Kenneth M. Humphrey, M. S., Instructor in Science Methods, Syracuse University. Paper. 128 pages. 21x27.5 cm. 1928. D. C. Heath and Company, 239 West 39th Street, New York. Price 84 cents.

Charts for Civics, Geography, Arithmetic and General Science, by Fay Campbell, Formerly teacher of Civics and Geography, Lake View High School, Chicago. Paper. 96 pages. 21x27 cm. 1928. Wheeler Publishing Company, 2831-35 South Park Avenue, Chicago, Ill.

Radio, A Study of First Principles, by Elmer E. Burns, Instructor in Physics, Austin High School, Chicago, Ill. Cloth. 290 pages. 13x18 cm. 1928. D. Van Nostrand Company, Inc., 8 Warren St., New York.

The Elements of Industrial Engineering, by George Hugh Shepard, Professor of Industrial Engineering and Management, Purdue University, Lafayette, Indiana. Cloth. Pages xii+541. 14.5x23 cm. 1928. Ginn and Company, 15 Ashburton Place, Boston. Price $4.80.

Physics Review Book, by Arthur H. Killen, Flushing High School, Flushing, L. I., N. Y. Cloth, Pages iv+283. 13x19 cm. 1928. Oxford Book Company, New York. Price, Paper 68 cents and Cloth 80 cents.

Advanced Algebra, by Herbert E. Hawkes, Ph.D., Professor of Mathematics in Columbia University. Revised Edition. Cloth. Pages vii+302. 13.5x20.5 cm. 1928. Ginn and Company, Boston. Price $2.00.

Physical Education Teaching Manual, by Frederick William Maroney, M. D., Director of Health Education, Atlantic City, New Jersey. Cloth. Pages viii+397. 13x18.5 cm. 1928. Lyons and Carnahan, 221 East Twentieth St., Chicago.

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Mathematics in Liberal Education, by Florian Cajori, Ph.D., Professor of the History of Mathematics in the University of California. Cloth. 169 pages. 13x20 cm. 1928. The Christopher Publishing House, Boston, U. S. A. Price $1.50.

Sir Isaac Newton, 1727-1927, A Series of Papers Prepared under the Auspices of The History of Science Society. Cloth. Pages ix+351. 15.5x23.5 cm. 1928. The Williams and Wilkins Company, Baltimore. Price $5.00.

Thr Kingdom of the Mind, by June E. Downey, Professor of Psychology in the Univrrsity of Wyoming. Cloth. Pages x+207. 12.5x19 cm. Macmillan Company. 1927. Price $2.00.

A Guide to The Constellations, by Samuel G. Barton, Ph.D., Assistant Professor of Astronomy, University of Pennsylvania and Wm. H. Barton, Jr., C. E., M. S., Assistant Professor of Highway Engineering, University of Pennsylvania. First Edition. Cloth. Pages x+74. 23x30.5 cm. 1928. McGraw-Hill Book Company, Inc., New York. Price $2.50.

BOOK REVIEWS.

Bobbs-Merrill Algebra, by W. R. Krickenberger, Department of Mathemathics, Arsenal High School, Indianapolis, L. H. Whitcraft, Head of the Department of Mathematics of the Indiana State Normal School, Eastern Division, and A. M. Welchons, Department of Mathematics, Arsenal High School, Indianapolis. 394 pages. 14.5x19 cm. 1927. Indianapolis. Bobbs-Merrill Company.

The authors have aimed to produce an algebra which will not only meet the requirements of students preparing for college or for advanced courses in mathematics, but which will also serve the needs of those who will receive no further training in mathematics.

The following features deserve attention.

1. There is an introduction which gives a review of fractions, including decimals and percentage. In this introduction there is a brief treatment of angles and simple mensuration of plane figures.
2. The meaning, use, and manipulation of the formula is emphasized.
3. Factoring, which has little value for the high school freshman, is placed at the end of the book.
4. There are applications to geometry and physics which are interesting both from the standpoint of general information and as ground work for future study of these subjects.
5. There are interesting problems in numerical trigonometry.
6. A graded review follows each chapter.
7. There is a supplement containing more difficult problems which is designed to take care of the stronger pupils.

J. M. Kinney.

Radio, A Study of First Principles, by Elmer E. Burns, Instructor in Physics, Austin High School, Chicago. Cloth. 290 pages. 13x18 cm. 1928. D. Van Nostrand Company, Inc., 8 Warren St., New York.

This is a book for every home as well as for every school—a book that tells in easy, understandable language all the fundamental principles of radio. Every technical term used is fully explained. Nearly every page contains one or more diagrams. All effects are explained on the basis of electrons in action. The author is a master of the art of making difficult topics easy. Good examples of this are his explanation of hysteresis in the third chapter, and of induced currents and electric resonance later on. Altho the book is intended to be used as a text the descriptions of illustrative experiments are so definite that teachers or pupils will be able to perform most of them without need of a laboratory manual. The book completely fills the textbook gap that has been so obvious since the radio age began and people of all ages and occupations began to demand instruction in radio. No previous knowledge of physical science is necessary hence the book is a suitable text for elementary classes in the regular schools and for classes of adults in special schools. Every teacher of elementary science, electricity or physics in junior or senior high school will want this book.

G. W. W.

Problems of Modern Physics. A course of Lectures delivered in the California Institute of Technology, by H. A. Lorentz, Professor of Mathematical Physics in the University of Leiden. Edited by H. Bateman, Professor of Mathematical Physics in the California Institute of Technology. Pp. vi+312. 1927. Ginn & Company. $3.60.

The late Professor Lorentz (1853-1928) once remarked that a hundred years from now this time will be known as the time when Einstein created the Theory of Relativity rather than as the time of the World War. Indeed, the importance of the recent development of physics can hardly be overestimated. While our knowledge has been extended to regions which were considered forever beyond human reach, a multitude of new facts have been discovered which defy description by the theories of classical physics and present problems of the utmost difficulty to the theoretical physicist. The attempts made to solve these problems, represented by the Theory of Relativity and the Quantum Theory, involve a revision not only of theories which were considered well established but even of our most fundamental concepts. Space and time have been fused together into the concept of space-time. Energy and mass have become synonymous. A certain dualism or complementarity seems unavoidable, the wave concept as well as the particle concept being needed for the description of both matter and radiation. A space-time description of the processes inside the atom, and hence the application of the idea of causalty to such processes, seems impossible.

The present volume is an excellent introduction to the study of modern physics. Written as it is by a man who was a distinguished leader in theoretical physics for half a century, it gives the right perspective and background. Only the more essential things are treated, and unsolved problems and difficulties are continually pointed out.

The first lectures are quite elementary and deal with the propagation of light. Hereafter follows a brief treatment of the electron theory, including a discussion of the experiments of Tolman and Stewart and of the molecular scattering of light. The propagation of light in ponderable bodies is next taken up. The Michelson-Morley experiment is explained, and a simple treatment is given of the special theory of relativity. The brief treatment of Bohr's theory of atomic structure which follows forms an interesting supplement to the more detailed treatises on the subject. The last lectures are devoted to the generalized theory of relativity. An appendix contains a number of notes largely of mathematical nature.

Professor Bateman deserves credit for his careful editorship. The style is clear, and no logical steps are left out. The book should form interesting and fairly easy reading even for readers with only a moderate knowledge of physics and mathematics. J. Rud Nielsen, University of Oklahoma.

Self Proving Business Arithmetic, by Theodore Goff, Head of the Department of Commercial Mathematics, State Teachers' College, Supervisor of Commercial Arithmetic, State Teachers' College High School, Whitewater, Wisconsin. Pp. xxiii+645. 14x19.5 cm. 1928. New York. The Macmillan Company.

This arithmetic has been designed for commercial students. It is divided into two parts of Nineteen chapters each. This division is made for the purpose of accommodating schools which have nineteen-week terms. Each part is also divided into sixty-five lessons which may be given at the rate of one per day if desired.

Among the interesting features are the following:

1. The author provides for the proof of every problem. The student is required to solve each problem in two different ways, one on one side of the sheet according to the directions of the author; the other on the reverse side of the sheet by a method of his own choice.
2. All topics included in it have a direct bearing on business and are treated from a modern business standpoint.
3. The student is given "sets" of problems to work, in the solution of which he is to imagine himself employed in some important capacity.
4. This arithmetic is designed to correlate with bookkeeping in every detail without overlapping. J. M. Kinney.

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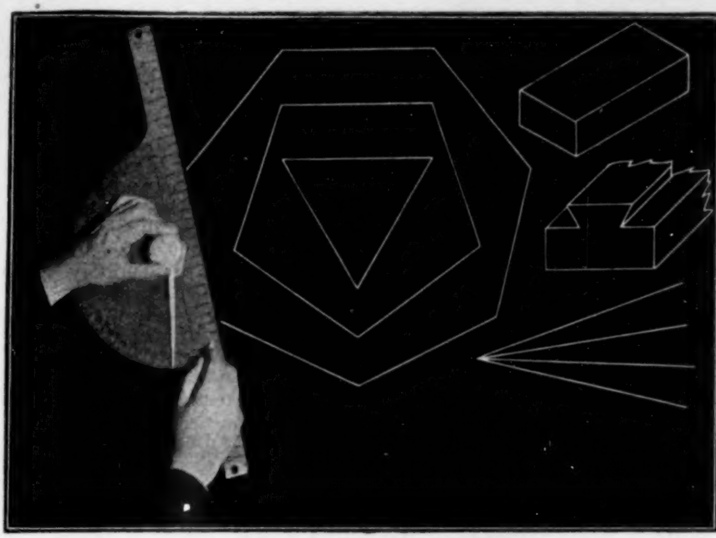

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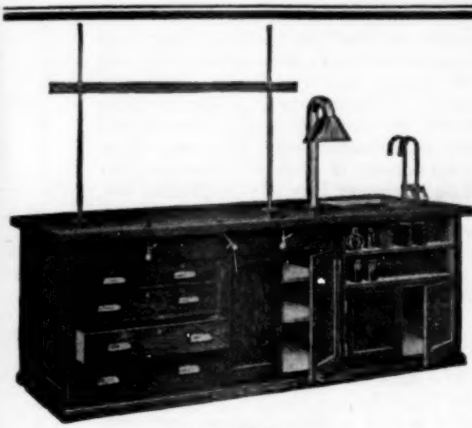

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Physics for College Students, an Introduction to the Study of the Physical Sciences, by A. A. Knowlton, Ph. D., Professor of Physics, Reed College. Cloth. Pp. xix+641. 14x23 cm. 1928. McGraw-Hill Book Co., Inc., 370 Seventh Avenue, New York. Price $3.75.

Within the past two years several new texts in general physics of college grade have appeared and other standard texts have been revised and improved both by the inclusion of new material and by giving more attention to the language used, but practically all have followed the divisions of subject matter established by the pioneers nearly a century ago. In this respect Professor Knowlton has produced a book that is decidedly different: the familiar divisions, Mechanics, Heat, Electricity, etc., have given place to a sort of cyclic arrangement which the author believes is advantageous for beginning students, especially those not primarily interested in physics as a technical subject. This arrangement permits the teacher to introduce the more familiar parts early in the course and to keep contact with the fundamental principles underlying energy changes in all physical phenomena. Energy is the central theme around which the book is built, and the methods of measuring energy in its various forms and its relation to matter are introduced early in the course. Later the student makes use of these same methods and principles in the study of less familiar phenomena, now made easier because the method of approach has been used before and the student observes them in their proper relations.

The author has constantly kept in mind the tendency of the nontechnical student to ask the question "Why study this?" Each chapter is short enough to be read at one sitting and is introduced by a short topic which points out the main object of study. Each chapter is followed by a brief summary, a graded set of numerical problems, and a list of readings with page references selected mostly for their humanizing value.

It is the reviewer's opinion that the author has produced a thoroly modern text which will be influential in improving college physics teaching. No doubt those who have spent years in developing a *logical* course and who have carefully arranged their laboratories so that no piece of electrical apparatus is ever permitted to contaminate the heat laboratory will find this *pedagogical* course objectionable on the ground that it is not practicable to interweave the customary divisions of the subject. There is some real basis for this objection especially where crowded conditions prevail and funds are limited, but the difficulty is probably more apparent than real, at least so long as laboratory courses consist of a rather fixed number of definitely outlined experiments. The reviewer heartily applauds Dr. Knowlton's very serious attempt to make the physics course a "fascinating and inspiring story of man's progress in mastery of his physical environment" without sacrificing the technical value of the subject, and recommends that the book be given serious consideration in all physics departments. Every high school should have it on the reference shelf.

G. W. W.

Biology of the Vertebrates, by Herbert Eugene Walter, Professor of Biology, Brown University. xxv plus 788 pp., 687 figures. The Macmillan Company. 1928.

This new work serves every purpose of a text in comparative anatomy, but it is much more. Together with a treatment of morphology, the book brings together much material of taxonomy, chorology, paleontology, anthropology, cytology, histology, pathology and embryology. These are discussed in Part I of the text, while physiology is stressed in connection with structure all through the book.

The book is divided into three parts which are headed, "The Background," "The Mechanism of Metabolism and Reproduction," and "The Mechanism of Motion and Sensation," respectively.

As to subject matter and organization, the book is unique in its field and the author shows superior skill in presenting fundamental facts in an interesting way. The work will form the basis for a live course for premedics and it suggests a superior course in Vertebrate Zoology for the

student of general zoology. With courses of this type offered, more and more of the general students will elect advanced courses in animal biology. We have needed this type of instruction in the preparation of teachers of science in the high schools.

The book is not only well written and illustrated, but the publishers are to be commended for the mechanical make-up and binding.

Jerome Isenbarger.

Animal Biology, by J. B. S. Haldane and Julian Huxley. xvi plus 344 pp. 122 figures. Oxford University Press, American Branch, New York. Price $2.50. 1927.

For a number of years, writers of texts in elementary biology have been inclined to a stressing of the economic side. The book which is the subject of this review is pure biology, unadulterated by any attempt to sacrifice fact for effect. It will make a special appeal to those persons who desire to secure a background of biological information as a basis for an understanding of some of the fundamental facts of animal life. The central idea which determines the organization of materials is organic evolution.

The book is intended to be used for general reading and to furnish material supplementing the class-room and laboratory instruction. Development of an appreciation of scientific method is clearly aimed at rather than an accumulation of a large quantity of detailed facts. No bibliography or reference guide is given and there are no teaching suggestions. It is in the form of a reader and should not only form a helpful source of material in the regular science courses, but it should also prove a valuable aid in the modern "Science for All" movement.

Jerome Isenbarger.

Plane Geometry, by W. W. Strader and L. D. Rhoads of the Wm. L. Dickinson High School, Jersey City, New Jersey. Pp. xvi+399. 14x19 cm. 1927. Philadelphia. The John C. Winston Company.

In the opinion of the reviewer this text stands among the best of the remarkably well written geometries that have appeared during the past two or three years. Among the many interesting features we list the following:

1. The book presents such a pleasing appearance that it will tend to create in the mind of the student a favorable bent toward geometry.
2. There is a minimum course which includes all the propositions required by the College Entrance Examination Board and recommended by the National Committee. It covers 243 pages of the text.
3. Provision is made for the more brilliant students in the miscellaneous exercises at the end of each chapter and in the supplement at the end of the book.
4. There are numerous Oral Exercises which are designed to compel the student to think about the definitions and theorems which they follow.
5. Development exercises are used to introduce new kinds of work.
6. Specific directions are given for proving certain families of theorems.
7. Summaries of families of theorems are added for emphasis and reference and for the purpose of securing continuity.
8. A large number of illustrations, of which many are full page, increase the attractiveness of the book.
9. There are numerous examples of the New Type of Geometry Examinations.

J. M. Kinney.

Mathematics for Agriculture and Elementary Science, by H. B. Roe, Associate Professor of Agricultural Engineering, University of Minnesota, D. E. Smith, Professor Emeritus of Mathematics, Columbia University, and W. D. Reeve, Professor of Mathematics, Teachers College, Columbia University. Pp. v+354. 15x21.5 cm. 1928. Price $2.80. Boston. Ginn and Company.

This book is designed primarily to take care of the needs of freshmen students in colleges of agriculture and other institutions of collegiate grade which offer a course in general mathematics and which desire to

give the student an insight into the practical value of mathematics. There are also many high schools which offer courses in mathematics of collegiate grade. Such schools might use this book with profit.

J. M. Kinney.

College Algebra, by A. M. Harding, Professor of Mathematics, University of Arkansas, and G. W. Mullins, Associate Professor of Mathematics, Barnard College, Columbia University. Pp. vii+324. 13.5x19.5 cm. 1928. New York. The Macmillan Company.

This algebra contains material of the standard text. As usual there are many independent chapters which may be omitted or taught in some other order than that of the text. There are many exercises. The graph is used chiefly for the purpose of explaining algebraic processes. The derivative is introduced and applied in the chapter on quadratic equations and again in the chapter on the theory of equations.

J. M. Kinney.

SCIENCE QUESTIONS.

Conducted by Franklin T. Jones

Questions for discussion, examination papers, disputed points may be submitted to this department. They will be published together with discussion.

Please let us know what you are working on. It will be helpful to pass the information along.

Please send in tests and examination papers.

Send all communications to [illegible] home address—Franklin T. Jones, 10109 Wilbur Ave., Cleveland, Ohio.

THE BIG QUESTION.

518. *Suggested by recent criticisms of science teaching. What arouses enthusiasm in science classes?*

Please think over the past year, select that day, or week, or topic that stands out above all others, and write a letter about it to the Editor of this department (address as above).

There are 7,000 subscribers to School Science and Mathematics, at least 700 will read the above question. Will you be one of the *one per cent* who will answer? Thanks!

OTHER QUESTIONS.

519. *Suggested by the reading of a standardized test.*

What do you think of the so-called standardized tests in the sciences? Do they—

a Measure the students' knowledge of physics, or chemistry, or general science, or biology, and so on?
b Stimulate the student to study?
c Guide the instructor in finding mistakes in his teaching?
d Afford a field of research for graduate students?
e If none of the above or in addition, what do they do?

The Editor believes that the answer of the teacher and the answer of the student himself would be valuable to readers of this Journal.

Please give this matter a few minutes time and let others have the benefit of your beliefs and experience. Your name will be withheld if you so request.

520. *Suggested by a statement* in Science, April 13, 1928.

a Have you ever heard "water hammer" in steam pipes, or radiators?
b What causes it?
c Can it be prevented.
d What answer do students give, steam fitters, engineers, teachers?

[Pupils and teachers are invited to send in answers. Some of the best answers will be published.]

521. *Proposed by Douglas I. Bates, Professor, College of Engineering, Oregon Institute of Technology, Portland, Ore.*

Do we judge the color of light from its wave length or its frequency; that is, light as it goes from one medium to another in which its velocity is different has its wave length changed but not its frequency? Does its color change?

A CRITICISM.

509. *Original problem submitted by Charles Woolley, Ridgewood High School, Ridgewood, New Jersey.*

A boy on a train moving at the rate of 45 miles per hour plays a stringed instrument. A string a meter in length and 1 1-2 mm. in diameter vibrates 380 times per second, the temperature being 77°F. If the string be made 500 mm. in length and 3 mm. in diameter, at the end of 2 seconds a note corresponding to how many vibrations per second will reach the listener who watches the train approach.

Answers by Charles Woolley.

1. No change in vibration rate of string.
2. 45 miles per hr. = 66 ft. per sec.
3. 77°F = 25°C.
4. Velocity of sound at 25°C = 1140 ft. per sec.
5. 3′ = wave length.
6. 22 more pulses reach ear at end of a second.
7. 44 more pulses reach ear at end of 2 seconds.
8. 424 vibrations (*answer*).

Answer by Fred G. Anibal, The University High School, The University of Chicago, Chicago, Ill.

Referring to the solution of problem No. 509 of the Science Questions, School Science and Mathematics, XXVIII, No. 4 (April, 1928), p. 424.

I find some difficulty in understanding the proposed answer in point 8. The question is, "a note corresponding to how many vibrations per second will reach the listener who watches the train approach?" The answer given is 424 vibrations.

I can agree that the Doppler effect upon the approaching sound will result in twenty-two more vibrations reaching the listener during the first second as indicated in point 6 of the solution. I can also agree that 44 more vibrations will reach the listener in two seconds but not 44 more vibrations per second as perhaps indicated in point 7 of the solution.

It seems to me that the listener will hear a sound having a vibration rate of 22 more per second than the rate of the vibrating string which is vibrating at the rate of 380 per second. The note heard by the listener who watches the train approach will have a frequency of 402 per second at the end of either the first or second second.

Otherwise there would be a constant increase in the rate of vibration of the note as the train approached and the pitch of the note heard by the listener would depend quite as much on the distance of the vibrating string from the listener as upon either the rate of vibration of the string or the speed of the train.

I would appreciate your consideration of the points suggested.

[What do others think about it?—Editor.]

SOLUTIONS AND ANSWERS.

513. *Proposed by Sudler Bamberger, Harrisburg, Pa.*

A falling body moves through such a great distance, we must take the variation of g, the acceleration of gravity, into account since the formulae of freely falling bodies will be inapplicable. Find the formulae that are.

Solution by L. S. Geiss, Austin Senior High School, Austin, Minn.

The force of attraction between the earth and any object is given by the equation:

$$F = K\frac{mm^1}{d^2} \qquad (1)$$

where m is the mass of the object, m' the mass of the earth and d the distance between their centers.

By the definition of force:

$$F = mg$$

where g stands for the acceleration produced upon the body of mass m, by a force F. Solving (2) for g, we get:

$$g = \frac{f}{m} \qquad (3)$$

Substituting the value of F from (1) in (3):

$$g = \frac{Kmm'}{md^2} = \frac{Km'}{d^2} \qquad (4)$$

However, the mass of the earth, m', is constant, so we can include it along with K in a general constant, K':

$$g = \frac{K'}{d^2} \qquad (5)$$

To evaluate the constant K', we shall consider an object at the surface of the earth. Here g is 980 cm per second and d is 4000 miles, so:

$$980 = \frac{K'}{4000^2} \qquad (6)$$

Or:

$$K' = 980 \times 4000^2 = 15{,}680{,}000{,}000$$

Substituting this in equation (5), we get our final equation, which is:

$$g = \frac{15{,}680{,}000{,}000}{d^2} \qquad (7)$$

where g is the acceleration of gravity, in centimeters per second per second and d is the distance from the center of the earth to the center of the object in miles.

For obvious reasons, the formula does not apply for positions beneath the surface of the earth.

Statistical evidence that the first-born child in a family is more likely to have certain malformations of mind and body than later children, and that such malformations are not likely to recur in later births in the same family, was presented by Dr. G. F. Still, professor of children's diseases at King's College, London.—Medical Progress in 1927.

"PERFECT" DIET GIVES VITAMIN CLUE.

The day when we shall live on synthetic concentrated pills of food is yet far distant. Yet science's latest attempts to raise laboratory animals on an artificially devised diet of pure foods, have led to the discovery of the new vitamin F, recently announced by Dr. Herbert M. Evans of the University of California.

When a diet of purified food elements consisting of casein, recrystallized cane sugar, certain necessary salts and the five recognized vitamins, A. B. C. D and E, was fed to rats in the laboratories of the department of anatomy, the animals failed to reach more than half size. Theoretically this diet contained all the elements necessary for the health and happiness of rats, but actually something else was necessary. Growth stopped altogether and the animals remained sexually immature. Natural food had to be resorted to, to supplement what might be called a chemically pure menu in order to reawaken their growth and convert them into healthy adult animals.

"Among the natural foods, lettuce and liver were the most potent," declared Dr. Evans, "and they, therefore, almost certainly contain a new sixth member of the vitamins, to which designation F will be given."

Lettuce when heated and dried failed to give the good results of the fresh product, the investigation showed.

Dr. Evans has to his credit also the discovery of vitamin E, at one time known as vitamin X, a lack of which brings about sterility. Oil from the germ of the wheat grain is thus far the most potent source of this necessary food factor.—*Science News-Letter.*